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PREFACE.

THIS Volume is partly based upon copyright material issued by the Publishers in another form; but by far the larger portion is new, and has been written expressly for the present work; while the whole has been brought into harmony with the advanced state of science and mechanism as applied to the chief means of locomotion and intercommunication.

Railways and Railway Companies are not treated in detail, the number being far too great; but the chief features of the railway-system, as developed in the net-works which now intersect the principal countries of the world, are presented in a plain and succinct way.

Steamers, treated as the successors of, and supplements to, the old sailing-vessels, are described in their steps of advancement towards the two grandest applications—Ocean Mails and War Fleets; while due attention is given to the wonderfully rapid manner in which the Paddle, the Screw, and the Iron-clad have revolutionised the navies of Europe and America.

Telegraphs—the electric system superseding the old mechanical semaphores—are tracked over the various lands of the earth, and then through the principal oceans and seas. A full account

is given of those marvellous submarine cables wnich now lie immersed two miles down in the bosom of the Atlantic, and which have had such an eventful ten-years' history.

Half a century's 'Annals' of Railways, Steamers, and Telegraphs, separately, present some of the leading facts under their proper dates in a convenient form.

A full Alphabetical Index affords ready means of reference.

GEORGE DODD.

January 1867.

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CHAPTER I.

RAILWAYS.

§I. ROADS AND VEHICLES BEFORE RAILWAYS.

IT almost necessarily results, from the very nature of the subject, that roads and vehicles will undergo improvement simultaneously. A good vehicle loses half its efficiency on a bad road; a good road loses half its value if none but bad vehicles run upon it. Men probably rode on horses and mules, asses and camels, elephants and dromedaries, before there were any vehicles at all. In mountainous countries, where roads can with difficulty be constructed, the pack-saddle is one of the most natural modes of transporting merchandise; while the sedan, the litter, and the palanquin suggest themselves to the traveller who is rich enough to consult his own ease. Possibly a sledge, fitted to glide over grass, flat ground, ice, or snow, was the first, as it was the simplest, form of carriage; such sledges are still used for conveying wine-casks in some parts of Madeira; and even in London, a massive brewer's drayman, sitting ladywise on a massive horse, may occasionally be seen drawing a cask of ale along the streets on a small sledge. As sledges will work smoothly only on certain kinds of surface, and as litter and sedan carriers are rather costly appendages to travelling, there was an evident temptation to place a rounded log as a roller

under a sledge or flat vehicle, so pivoted as to roll along the ground while it rotated. It is almost certain that such rollers preceded actual wheels. Men of intelligence would soon perceive that the roller is not needed in its entire length, but only near the ends; and hence two discs, two slices from a rounded log, would suffice. Here we have at once the principle of the wheel; indeed, such log-slices are used as wheels to the present day in some of the ruder districts of South America. Next, as logs are usually not bulky enough to yield large slices, and as wheels of large diameter are nevertheless suitable for easing draught, it was a natural improvement to build up wheels with separate pieces of wood, more or less strengthened with iron. This invention of wheels was perhaps the greatest incentive towards the making of good roads. There were strong inducements so to improve the trackways that the wheel should not receive undue jarring, and should not sink into soft ground. A notable advance was made when four wheels were used: seeing that it permitted the use of a much larger vehicle than before, and the carrying of much more merchandise at one time. It was a refinement when traces and shafts were so managed that two or more draught animals could be employed either in file or abreast; it was a refinement when the front wheels were made lower than the hinder pair, that they might turn on a pivot underneath the carriage, and thus enable the vehicle to wheel round sharp curves easily; and it was a further refinement when springs were introduced, to lessen the shock and jolting otherwise unavoidable.

By what steps the roads improved, to render them worthy of the gradually-improved vehicles, it needs no very elaborate research to ascertain. An Indian path through those parts of America which are still in a rude state, or a narrow path through an English cornfield (from which the farmer would willingly exclude the public if he could)—this is the most primitive of all roads. The earliest British roads that we know anything about were not regularly made or engineered; they were simply tracks, mostly following the highest ridges of land

from town to town, and marked out by the feet of the pedestrians. In the lapse of ages, many of these tracks were worn down far below the general level of the ground. There is still traceable one of these *trackways* or *ridgeways* in Berks and Wilts, in some places deserted and unused, in others still adopted as country lanes. There were also *fossways* of more importance, forming the main roads in various directions out of London. Portions of these old fossways are traceable on our maps, under the names of Watling Street, Ikenield Street, Ermin Street, and Verulam Street. The first of these names is still retained by that famous city thoroughfare which we now associate with far other thoughts than those of blue-painted and skin-clad Britons.

But the Romans were the most famous road-makers of the old days. Borrowing the idea of paved roads from the Carthaginians, they set to work with that practical common sense which characterised them, and constructed roads from their capital city to every quarter of their mighty empire. With them the principal object was to have the roads straight and level; they understood well the importance and advantage of facile means of transit and communication, and with singular skill and boldness they pierced or excavated hills, built bridges and viaducts, and raised embankments, remarkable alike for their extent and their durability. In Italy alone there were several thousand miles of public highways; of these, the 'Queen of Roads,' or 'Appian Way,' 142 miles in length, is the most noteworthy. It was constructed by Appius Claudius 310 years before the birth of Christ; and Procopius, writing in the sixth century, says of it: 'To traverse the Appian Way is a distance of five days' journey for a good walker, and it leads from Rome to Capua; its breadth is such that two chariots may meet upon it and pass each other without interruption; and its magnificence surpasses that of all other roads. For constructing this great work, Appius caused the materials to be fetched from a great distance, so as to have all the stones hard and of the nature of millstones, such as are not to be found in this part of the country. Having ordered this

material to be smoothed and polished, the stones were cut in corresponding angles, so as to fit together in joinings without the intervention of copper or any other material to bind them, and in this manner they were so firmly united, that in looking at them one would say they had not been put together by art, but had grown so upon the spot; and notwithstanding the wear of so many ages—being traversed daily by a multitude of vehicles and all sorts of cattle—they still remain unmoved; nor can the least trace of ruin or waste be observed upon these stones, neither do they appear to have lost any of their beautiful polish. Such is the Appian Way.' Much of this description remains true even at the present day; and the road, after the lapse of more than 2000 years, still presents an instructive model to the modern engineer.

With the exception of the Roman highways, the public thoroughfares in ancient Britain scarcely deserved the name of roads. Some of our old British and Roman roads accompany or cross each other; and, in some instances, the Romans adopted and improved into a road a track made by their predecessors. When the Saxons came, they found Roman 'military' roads and British 'country' roads; they improved a little on the latter, but never equalled the former. During many centuries, most of the roads were mere tracks across the country, patched with rude paving in the softer places, and 'very noisome and tedious to travel on, and dangerous to all passengers and carriages,' as declared in the act imposing statute labour for the repair of the highways in the reign of Mary. The labour when performed was capricious, not systematic: people mended such portions as traversed their farms or estates, and left the rest to take care of itself. A statute was passed in the reign of Henry VIII., authorising parishes to raise rates for keeping their public ways in repair; but this was little attended to in country places.

The first attempt at real improvement may be considered as dating from the passing of the first turnpike act in 1653, of which the preamble stated that parts of the great north road leading to York and Scotland were 'very ruinous and become

almost impassable, insomuch that it is become very dangerous to all his majesty's liege people that pass that way.' In the reign of Charles II. the taking of tolls was first established on a turnpike-road leading from Hertfordshire to the counties of Huntingdon and Cambridge. Many quarrellings, however, arose; and the military were sometimes called out to quell rioting on the part of those who disliked the innovation. So slow was the progress of improvement, that the roads throughout the country were but little changed for the better during the next hundred years; many became worse, and some which had been wide were narrowed by encroachments and neglect. According to Stow, wagons were in use on some roads for the conveyance of goods and passengers as early as 1541; but most of the traffic was carried on by means of packhorses, which, tethered together in long trains, made their way slowly and painfully along the causeways;* and whoever met them was obliged to step off into the mire on either side to get out of their way. 'The people of Kendal,' says Roger North, writing in 1676, 'could write to most trading towns and have answers by the packs—for all is horse-carriage—with returns, time being allowed, as certain as by the post.' In 1609, to send a letter from York to Oxford, and get back an answer, took a whole month; and even after the establishment of the post in 1660, correspondence was but little expedited. The introduction of coaches, asserted a writer of the day, would ruin the country; the wagons mentioned by old Stow were advocated as 'travelling easily, without jolting men's bodies or hurrying them along,' which the obnoxious coaches did, at four miles an hour. Stage-coaches were also at first objected to by many country towns, on the ground that they would 'injure trade,' by enabling the metropolis to avail itself of a wider circle of supply and demand. In 1673, travellers were kept a week on the road between London and Exeter, the fare being 40*s*. in summer and 45*s*. in winter: the same fare was

* The word *causeway* or *causey* was first used by the Normans, who derived it from the French *chaussée*.

charged from London to Chester or York. In 1678 a six-horse coach took six days to perform the journey from Edinburgh to Glasgow and back. At the end of the seventeenth century the stage-coach with six horses occupied two days in the journey from London to Cambridge, 57 miles; and fifty years later the journey to Oxford consumed the same time. Travelling by night was first introduced about 1740, not without opposition from those who foreboded ruin in any departure from old practice. Hogarth's picture, 'The Country Inn Yard,' brings before us the ordinary coach of the period. In 1750, the 'Alton and Farnham Machine' was started with a wicker-basket slung behind for the outside passengers. It was not uncommon at that period for people whose business led them from the Scottish to the English metropolis to make their wills before starting. The journey was indeed a formidable one, as may be gathered from an advertisement in the *Edinburgh Courant* for 1758, stating that, with God's permission, the coach would 'go in ten days in summer and twelve in winter.' In 1765, a 'flying-coach,' drawn by eight horses, travelled from London to Dover in a day, fare 21*s.*

Arthur Young's experiences during his 'Tour' in 1770 furnish conclusive evidence as to the condition of the roads at a still later date. He was travelling in Lancashire, a county now among those best furnished with railways, and says: 'I know not, in the whole range of language, terms sufficiently expressive to describe this infernal road. To look over a map, and perceive that it is a principal one, not only to some towns, but even whole counties, one would naturally conclude it to be at least decent; but let me most seriously caution all travellers who may accidentally purpose to travel this terrible county to avoid it as they would the devil, for a thousand to one but they break their necks or their limbs by overthrows or breakings-down. They will here meet with ruts, which I actually measured, four feet deep, and floating with mud, only from a wet summer—what, therefore, must it be after a winter? The only mending it receives in places is the tumbling in some loose stones, which serve no other purpose but jolting a carriage in the most

intolerable manner. These are not merely opinions, but facts; for I actually passed three carts broken down in these eighteen miles of execrable memory.' This was not the only instance of bad roads that Young met with; he came upon others further north, and denounces them in language equally emphatic.

Concerning goods traffic, carts were gradually brought into use; and these were supplemented by larger and more formidable broad-wheel wagons, on such main roads as were firm enough to bear the weight.

On the eve of the nineteenth century travelling was still slow. Mr Porter states, that he 'well remembers leaving the town of Gosport (in 1798) at one o'clock of the morning in the *Telegraph*, then considered a fast coach, and arriving at the Golden Cross, Charing Cross, at eight in the evening; thus occupying nineteen hours in travelling eighty miles, being at the rate of rather more than four miles an hour.'

The time, however, had come for a change; and Telford and Macadam, by their improvements in road-making, prepared the way for more rapid locomotion. The insurrections in Scotland in 1715 and 1745 led to the formation of numerous roads, which penetrated the wildest districts of the Highlands, extending altogether to nearly 1000 miles in length. These improvements were made by slow degrees. The tortuous windings, the steep ascents and descents, the stony ruggedness of some roads, and the miry softness of others—all continued to a comparatively recent period. Telford was one of the first to insist upon the fact that road-making ought to be regarded as a worthy part of the civil engineer's study. He pointed out what ought to be the maximum angle of incline, and advocated a system of gentle curves as a medium between straight lines and sharp turnings. He saw that the substance of a road should be solid, smooth, gently convex, and provided with side-drains; and he spared no cost in bringing good stone to make the road solid. Thus real principles of construction were acted on, and the system of maintenance developed which gave to us some of the best roads in the world. In 1815, Telford commenced that grand memorial of

his ability—the Holyhead Road; a work that may safely be contrasted with the most famous highways of antiquity, regard being had to smoothness of motion; and though no longer required for the service of the mail, its preservation will, we hope, be diligently cared for by those to whose charge it is intrusted. The establishment of this road effected an important change in the communication with Ireland—as we shall see in a later page.

The prime object kept in view was to diminish friction, to render draught as easy as possible, and these desiderata were attained. Macadam, about 1816, began to shew that to spread a layer of broken granite over the natural soil, properly prepared and levelled, was the best mode of forming a permanent and serviceable road; and his principles were actively reduced to practice in nearly all parts of the kingdom. He adopted a maximum weight of about six ounces per fragment, and smoothly raked and made slightly convex the earth under the layer. His roads were far less costly than Telford's, because the latter engineer paved the substratum almost as carefully as the surface. Macadam occasionally employed scoriæ from ironworks, furnace ashes, burned clay, and baked sandstone, but granite whenever he could obtain it. The impulse once given, further improvements were continually sought after, and the result was a system of highways, of hard granite roads, as near perfection as mechanical and engineering science could make them. In some places 'granite tracks' or 'stone tramways' were laid down, and wherever tried were conducive to facility of transit. They had long been in use in the streets of Milan; and on Dartmoor a stone trackway was laid for twenty miles, from the quarries to Plymouth. A granite line was also laid from London towards the East India Docks along the Commercial Road; the Forth and Clyde Canal Company made use of iron for a similar purpose, and slate was employed in other quarters; but there was no difference in the results. One horse on the level track could do as much work as four on a common road.

The turnpike roads are now believed to be about 30,000 miles in length; and the smaller or parish roads, 120,000 miles.

These roads cost for their maintenance no less than £3,500,000 in 1858; and the amount is not likely to be less now.

While these improvements in roads were being gradually effected, a parallel series of improvements was observable in road vehicles. When Mr Palmer introduced mail-coaches in 1784, a commencement was made to that system of high speed which afterwards gave to English coaches a reputation quite unparalleled. Travelling by mail or stage-coach was prosecuted with such spirit and regularity as to make the roads a scene of continued animation and excitement. In 1837—nearly the end of the heyday of long stages—licences were granted to 3026 stage-coaches, of which 1507 went to or from London, besides 103 mail-coaches. The number of passengers per year about the period in question has been estimated at 2,000,000. The conveyance of these gave movement to a system of traffic unequalled in any part of the world. In no other country was there such promptitude, such celerity of transit; and in fine weather there was real enjoyment in sitting behind the four spirited horses, which, in their compact and well-kept harness, trotted along the roads at a speed varying from seven to ten miles an hour. Coachmen of the Weller school still live to tell the deeds of crack teams which exceeded even this speed. For the leisurely traveller the top of a stage-coach presented advantages for viewing scenery which constitute no part of railway accommodation. There was time to discuss the merits of a ruin or a landscape; the appearance and disappearance of one and the other were not then, as now, almost simultaneous; and conversation could be carried on with a chance of its being heard. Then there was variety in the road itself: now traversing a well-cultivated vale, curving in and out among pastures and corn-fields, at times pleasantly overshadowed by trees; anon rising over a hill, descending into a valley, skirting or crossing a running stream, penetrating at times the most picturesque parts of the land; going through—not past—towns and villages, where people ran to their doors and windows to see the vehicle speed by, and gazed after it with a feeling of pride as long as it

remained in view. The traveller then could make himself acquainted with much that was interesting along his line of route, and carry away a definite impression of the scenes which had passed before his eyes.

But there were drawbacks: exposure to wet or inclement weather; the rapacity of innkeepers who purveyed for travellers; that of their servants; and the fees to coachmen and guards, exercised and levied without compunction, and often with incivility, oppressive to all compelled to submit thereto, but more especially to persons of slender means. And furthermore, few working-men could afford to travel by stage-coach. The broad-wheeled wagon, creeping on at the snail's pace of three miles an hour, or the canal-boat, oftentimes as slow, was their only resource. In either of these the journey from London to Manchester occupied a week; and yet, with all their tedium and misery, they were much more resorted to by respectable people of scanty means than is commonly known or believed in the present day.

But what travelling was thirty years ago is, and becomes more and more, matter of history. Except in little-frequented parts of the country, stage-coaches and wagons have nearly disappeared. Having superseded less perfect machinery, they in turn were set aside by a power—*Steam*—more in accordance with the aims and requirements of the age.

Concerning merchandise traffic, the Pickfords, the Chaplins and Hornes, &c., had done all that good roads and good canals could enable them to accomplish. Of course, a heavily-laden broad-wheel wagon cannot travel other than slowly; but still the introduction of various improvements in the construction of the vehicles, the devising new modes of packing and arranging, the collecting and delivery of merchandise, and the establishment of effective systems of booking and classifying—all tended to improve the wagon service. If it had not dash and sparkle, like the *Quicksilver* and *Highflier* system of stage-coaching, it was at least solid and sturdy—like the broad-wheel wagons themselves.

§ II. EARLY DAYS OF RAILWAYS.

WHO invented Railways? is a problem as impossible to solve definitely as the companion problem—Who invented Steam Navigation? Many people did these things, each contributing his mite, and no one dreaming how grand the final result would one day be. 'Another remarkable thing,' said Roger North, writing in 1676, and referring to the neighbourhood of Newcastle-on-Tyne, 'is their *way-leaves;* for when men have pieces of ground between the colliery and the river they sell leave to lead coals over their ground; and so dear that the owner of a rood of ground will expect £20 per annum for this leave. The manner of the carriage is by laying rails of timber from the colliery down to the river exactly straight and parallel; and bulky carts are made with four rowlets fitting these rails, whereby the carriage is so easy that one horse will draw down four or five chaldron of coal, and is an immense benefit to the coal-merchants.' This account, as is obvious, refers to a mode of transport already established, and certainly involving the main principle of a railway—the laying down of smooth surfaces on which the wheels may run. Even if they had existed only ten years before Roger North wrote, such tramways would now be two centuries old. In 1738, a tramway was laid down from Cockenzie to the coal-pits of Tranent, across the ground on which, some years later, the Highlanders put General Cope to flight, and won the famous battle of Prestonpans. A portion of the line, which may still be traced, was selected as a position for the English cannon. About the same time iron trams were laid down at the Whitehaven collieries. The practice had been, as described by North, to make the rails of wood, and fix them parallel on cross-pieces called sleepers, embedded in the earth. Thin plates of iron were sometimes nailed on to protect those parts most exposed to wear—a precaution which could

scarcely have failed to suggest the idea of rails made entirely of iron. These were first introduced at Coalbrookdale in 1767, where, in order to keep the furnaces at work during a slack season, a number of bars five feet long, four inches wide, and one and a half inch thick, were cast to be used as rails instead of wood, with the intention of taking them up for sale in case of a sudden demand. All these early railways were used for vehicles the wheels of which had flanges, to prevent them from running off the line; they were small wagons, carrying two or three tons of coal, and drawn by one horse each.

The difficulty of keeping the wheels from slipping off was urged as an objection against the use of these rails, and obviated some years afterwards, in 1776—at a colliery belonging to the Duke of Norfolk near Sheffield—by casting rails with an upright flange or guide at one side. These being nailed to wooden sleepers, or, as subsequently (1793), to blocks of stone, the two flanges kept the wheels in place, and kept the wagons from running off the track. The form, however, presented certain inconveniences: dirt accumulated in the angle, and 'edge rails' were substituted, which, with modifications, have ever since remained in use. Those laid down at Lord Penrhyn's slate quarries in 1801 were oval in form, with the narrow edge upwards, in lengths of four and a half feet, and kept in place by a solid dovetail block cast on the lower edge, and fitted into an iron sleeper underneath. A flange on either side of the tire prevented any deviation of the wheels. The saving of power was such that two horses regularly drew a train of twenty-four wagons, each containing about a ton; and ten horses were found sufficient to conduct a traffic which had, on a common road, required 400.

Another form of rail, in section resembling a **T**, came into use in the northern mining districts. The descending portion was cast with a gradual sweep—technically 'fish-bellied'—from end to end, to give strength between the bearings. With this was first used the 'chair'—a supporter made of cast-iron, which, being fixed to the sleepers, received and held each lap-joint of

the rails. The wheels were kept from running off by a flange on the inner edge of the tire, while the shape of the rail was such as to prevent any lodgment of dirt on the surface. But in all these rails there was one essential defect—their liability to break; a defect that still remained, notwithstanding the attempts to overcome it by increasing the weight of the casting; and a fatal one, had wrought-iron not been available. Rails of this material were laid down in 1808, but proved unsuitable, owing to their square form, the only one in which they could then be manufactured; and it was not until 1820, when Mr Birkenshaw produced rails by a process of rolling—a species of wire-drawing on a stupendous scale—that the difficulty was overcome. Since then the texture of rails has been as remarkable for toughness and elasticity as it was formerly for rigidity and brittleness.

Gradually iron roads grew into use in coal-fields and the mineral districts; and by the close of the tenth year of the present century there were more than 150 miles in South Wales. The first attempt to take a systematic commercial view of their utility was made in 1800, by Dr James Anderson, in his *Recreations in Agriculture.* He proposed to construct railways by the side of the turnpike-roads, so as to follow the ordinary levels and lines of traffic; to commence with the highway from London to Bath. Where the road ascended a hill, the level was to be sought by going round its base, constructing a viaduct or piercing a tunnel; and so carefully were these contingencies discussed, that, with the exception of horses being the moving power, the doctor's plans and arguments might be almost literally adopted in a railway prospectus of the present day. One point particularly insisted on was, that the lines should be managed by government commissioners, not by companies, who would unite monopoly with speculation; and should 'be kept open and patent to all alike who shall choose to employ them, as the king's highway, under such regulations as it shall be found necessary to subject them by law.' No immediate result followed the publication of these views; no one had then thought of railways independent of other thoroughfares; and to border the

latter by iron routes was a scheme too impracticable to be entertained. Two years later, in March 1802, a communication from Mr R. L. Edgeworth appeared in *Nicholson's Journal*, calling attention to the same subject. To quote the writer's words, he had many years before 'formed the project of laying iron railways for baggage-wagons on the great roads of England;' but having been met by numerous and powerful objections, he had despaired of success. Among these was urged the first cost, and the continual charge for repairs. To obviate the latter, he proposed, instead of an enormous load in one car, to divide the burden among several smaller cars, whereby the wear of the rails would be materially diminished. Models of these cars had been presented to the Society of Arts, and their inventor rewarded with a gold medal. He afterwards made four other carriages, with cast-iron wheels working on friction rollers, and used them for some time on a wooden railway to convey lime for agricultural purposes. To test the merits of his plan, Edgeworth suggested that four lines of railway might be laid on ten or twelve miles of one of the great roads leading from the metropolis. The rails were to be made hollow from the bottom upwards, for strength and to save expense; broad at bottom, and rounded at the top, to prevent the lodgment of dirt and dust; and fixed to sleepers of stone, so that their upper surface should stand about four inches above the road. On these should run light wagons, each containing not more than one ton and a half weight. The two inner tracks were to be for goods, the two outer ones for passenger-carriages, to travel in either direction, and when they met, turn off by sidings to the wagon-ways. To obviate all difficulty with respect to the wheels of public or private vehicles, they were to be placed on 'cradles or platforms,' fitted and constructed to run on the rails. The horses that brought the carriage would drag it on to the cradle, or truck, as it would now be called, and, descending at the opposite end, draw it along the line—stage-coaches, six miles an hour, with one horse; hackney-coaches, eight miles; and with the greatest ease and safety, by night as well as by day. Hills were to be avoided by making a

circuit; but a perfect level was not absolutely insisted on: no insurmountable objection existed to 'a rise of one foot in ten.' Another part of the plan was the employment of steam-power with stationary engines, with which it would be 'not impossible, by slight circulating chains, like those of a jack running upon rollers, to communicate motion between small steam-engines, placed at a considerable distance from each other; to these chains carriages might be connected at will, and, when necessary, they might instantaneously be detached.'

There is yet another name connected with the development of our railway system which must not be passed over—that of Thomas Gray, a native of Leeds. He was in Belgium in 1816, when, hearing that a canal had been projected to connect the coal-field of that country with the frontier of Holland, he very earnestly recommended to Mr Cockerill, with whom he was acquainted, the making of a railway instead. His mind had been for some time directed to the subject; and in 1818 he shewed to his friends manuscript *Observations on a Railroad for the whole of Europe*, and soon after returned to England for the purpose of making his schemes public. In 1820, he published *Observations on a General Iron Railway, or Land Steam Conveyance, to Supersede the Necessity of Horses in all Public Vehicles: shewing its vast Superiority in every Respect over the present Pitiful Methods of Conveyance by Turnpike Roads and Canals.* In this work, among advantages to result from the new system, Gray shewed that fish, vegetables, agricultural and other perishable produce, might be rapidly carried from place to place; that two post deliveries in the day would be feasible; and that insurance companies would be able to promote their own interests by keeping railway fire-engines, ready to be transported to the scene of a conflagration at a moment's warning. The cost of construction Gray calculated at £12,000 a mile. He was decidedly in favour of direct lines by the shortest course. His plan included a trunk-line straight from London to Plymouth and Falmouth, minor lines to Portsmouth, Bristol, Dover, and Harwich, with an offset from the latter to Norwich; a trunk-line also from London to Birmingham

and Holyhead, another to Edinburgh by Nottingham and Leeds, and secondary lines from Liverpool to Scarborough, from Birmingham to Norwich; in short, his system, remarkable for its simplicity, comprehended all the important towns of the kingdom, and in many respects is preferable to that which now prevails. His plan for Ireland had a grand trunk-line from Dublin to Derry, another to Kinsale, and by lesser lines ramifying from these he connected all the chief towns of the island with the capital.

Whatever effect Gray's persevering labours may have had in directing attention to the subject of railways, in suggesting views to others, he himself gained neither reward nor honour. His late years were passed in obscurity as a dealer in glass on commission at Exeter, in which city he died in October 1848, at the age of sixty-one. The name and services of such a man ought not to be forgotten.

The foregoing paragraphs embody interesting evidence of the germination of ideas and the growth of intelligence: the time was coming for maturer aims and increased powers of realising them.

The first authorisation of a railway by act of parliament is said to have been that of the Surrey Railway—an iron track laid from Merstham to Wandsworth in 1801; and of a short line from Cheltenham to Gloucester. Both have since become adjuncts or portions of other and grander lines. Slowly the number increased, until the new railways sanctioned by special acts of parliament became 5 in 1805, 10 in 1810, 16 in 1815, 20 in 1820, and 32 in 1825.

In September 1825 a railway was opened which gave a most important impulse to the system. This was the Stockton and Darlington, leading from the mines near Darlington to the wharfs on the Tees at Stockton—the whole distance about twenty miles—for the transport of coal. At first the wagons were drawn by horses; and such was the effect of easy carriage, that the price of coal at Stockton fell from 18*s.* to 8*s.* 6*d.* per ton; lead was carried from the interior to the ships at greatly reduced rates;

and a brisk trade in lime sprung up which had not before existed. Shortly after the opening, two coaches were placed on the line for the conveyance of passengers—large, roomy vehicles, to carry twenty-six persons as a regular load, and in extraordinary cases half as many more, an addition which in no way interfered with the speed of the journey. They had no springs, and were intended to run backwards or forwards without being turned. A block of wood made to press against the tire of the wheels by means of an iron lever within reach of the driver enabled him to check the motion or stop suddenly when required. Ten miles an hour was the usual speed, and seemed scarcely to require an effort from the single horse that drew the load, so seldom was there any strain on the traces; and the smooth and equable motion of the coach was a constant theme of congratulation among the passengers. The line originally consisted of but a single pair of rails, with sidings at frequent intervals, at which vehicles or coal-trains passed each other. The fare from Stockton to Darlington—twelve miles—was *2s.* for the inside and half that sum for the outside. Traffic became so lively between the two towns, owing to the facility of transit, that in the first year the proprietors returned £500. 'An intercourse,' as was said, 'and trade seemed to arise out of nothing, and no one knew how; and altogether the circumstance of bustle and activity which appeared along the line, with crowds of passengers going and returning, formed a matter of surprise to the whole neighbourhood.'

The years 1825 and 1826 mark one of those periods in history when the speculative mania, always present in a commercial community, and more or less active, suddenly bursts into delirium: projects, however visionary, were eagerly taken up; shares in ideal mines were bought and sold with marvellous celerity; and thousands became dupes of their own folly or thirst for gain. Everything was to be done by steam: by means of coal-gas, people were 'to ride among the clouds at the rate of forty miles an hour, and whirl along a turnpike-road at the rate of twelve miles an hour, having relays, at every fifteen miles, of bottled gas

instead of relays of horses.' A writer of the day remarks: 'This nondescript gas-breathing animal, something of the velocipede family, is intended to crawl over the ground by protruding from behind it six or eight legs on either side in alternate succession.' And referring to the numerous schemes then put forward for railways, he continues: 'Nothing now is heard of but railroads; the daily papers teem with notices of new lines of them in every direction, and pamphlets and paragraphs are thrown before the public eye, recommending nothing short of making them general throughout the kingdom.' All the great towns of the north were to be connected by railways: Liverpool with Birmingham, Birmingham with London, London with Dover. The ironmasters—trade being slack, and having an eye to business—had the credit of fostering the speculative spirit for their own interests. 'All physical obstructions,' as Telford said, 'were forgotten or overlooked amid the splendour of the gigantic undertakings.'

Real enterprise was, however, steadily pursuing its aim amid all the excitement. Application had been made to parliament for leave to lay down a railway from Liverpool to Manchester—a work then become indispensable to those two increasing and important towns. At that period, and for some time afterwards, canal-boats and slow, heavy road-wagons were the only available means for the transport of heavy goods or bulky merchandise. The charge for conveyance from London to Yorkshire amounted frequently to £13 per ton, and even at this high cost the service was very imperfect. Beneficial as canals had proved, they were becoming inadequate to the growing requirements of trade. Besides the road there were two canals for the traffic between Liverpool and Manchester, the distance by the latter 55 miles, and the carriage of goods in some instances £2 per ton. Manchester was so entirely dependent on Liverpool for supplies of raw material, and the saving of time in transport so much an object, that any measure for an additional route was more a necessity than a speculation. It was notorious that goods were frequently conveyed from Liverpool to New York in less time than to Manchester. To make a third canal was impossible, as

the district afforded no more water than sufficed for the two already existing. A thousand tons of merchandise were sent daily between the two towns, and produced a yearly revenue of £200,000 to the carriers. On one of the canals the profits were so great, that the proprietors received the amount of their original outlay every alternate year. Reasonable compliance with their wishes would have satisfied the merchants, who sought only to secure prompt and certain means of transport, not to depreciate canal property. Failing in their object, a railway, which had from time to time been talked about, was again discussed. The 'Liverpool and Manchester Railway Company' was formed, and their prospectus issued in 1824. In the following year the bill came before parliament, and there encountered all the opposition which selfishness could invent or ignorance employ, as may be seen in the parliamentary records of the session. The bill, however, was successfully carried in 1826.

Some years before, the Duke of Bridgewater, on hearing the remark: 'You must be making handsomely out of your canals,' replied, somewhat chafed: 'O yes—they will last my time; but I don't like the look of these tram-roads: there's mischief in them.' The mischief—if such it was—was about to be realised. The duke's agent was conferred with on the subject of the railway, and an offer made him of shares, which he met by the churlish answer: 'All or none.' To us in the present day it may not be uninstructive to consider some of the forms under which the spirit of opposition strove to effect its purpose. Canal proprietors were among the first to bestir themselves: they consulted Telford 'as to the most advisable manner of protecting their property;' and the enlargement and extension of the Birmingham and Liverpool, and the Ellesmere canals, were recommended by the eminent engineer as a preliminary measure. The legislature even was not exempt from incredulity, to choose a mild term. George Stephenson's assertion, during his examination before a committee of the House, that it would not be difficult to make a locomotive travel 15 or 20 miles an hour, provoked one of the members to reply that the engineer could only be fit

for a lunatic asylum. If the opposition were to be believed, the laying down of a railway would inevitably reduce the value of land through which it passed, and landholders, by gradual though sure decline, be brought to the verge of ruin. As a million horses would be thrown out of service, no one of course would care about keeping up the breed; and not only were good horses to become as rare as peacocks, but the 8,000,000 acres of land that produced the oats were to return to a state of nature. A *Quarterly Reviewer* wrote: 'As to those persons who speculate on making railways general throughout the kingdom, and superseding all the canals, all the wagons, mail and stage coaches, post-chaises, and, in short, every other mode of conveyance by land and by water, we deem them and their visionary schemes unworthy of notice. The gross exaggerations of the powers of the locomotive steam-engine, or, to speak in plain English, the *steam-carriage*, may delude for a time, but must end in the mortification of those concerned.'

Parliamentary sanction once obtained, the Liverpool and Manchester Railway Company set to work upon their novel and important undertaking—novel, inasmuch as its scheme and magnitude exceeded all that had been previously attempted of a similar nature. Stephenson, who had already won a reputation, was appointed engineer; and a chief point determined on was that the line should be as nearly as possible straight between the two towns. In the carrying out of this design engineering difficulties were encountered, the overcoming of which called forth a vast amount of scientific knowledge, invention, ingenuity, and mechanical hardihood. Hills were to be pierced or cut through, embankments raised, viaducts built, and four miles of watery and spongy bog converted into a hardened road. The drainage and solidification of this bog—or Chat Moss, its local name—were among the first operations. It was too soft to be walked on with safety, and in some places an iron rod laid on the surface would sink by its own weight. An embankment 20 feet in height was commenced, and had been carried some distance across the treacherous soil, when the whole sank down

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and disappeared; and not until many thousand tons of earth had been deposited and swallowed up was a secure foundation obtained. At the softest part, known as the 'flow-moss,' hurdles thickly interwoven with heath were laid down; and upon these the earth and gravel for the permanent way. The successful formation of this part of the line was looked upon at the time as no unworthy triumph over physical obstacles. It was but the precursor of still greater enterprises. Other great works were the tunnels under Liverpool, forming direct passages to the docks and the passenger station. No less than 63 bridges were built at different parts of the line, most of them of stone and brick; capacious tunnels were excavated, and cuttings through elevations, out of which were taken more than 3,000,000 cubic yards of earth, stone, and gravel. These materials were used in the formation of embankments, for bridges, and other masonry. The double line of rails weighed 3847 tons, and the chairs which held them in place 1428 tons. The total cost amounted to £820,000—four times as much as had been estimated.

During the execution of the works a question of considerable importance had to be decided: whether horses, stationary steam-engines, or locomotives, should be the tractive power. The first two, however, were soon set aside; and early in 1829, when the works of the railway were well advanced, the directors advertised a prize of £500 for the best locomotive engine. The stipulations were, that it should draw at least three times its own weight—the latter limited to six tons—and be supported on springs, and not exceed fifteen feet in height; that it should be worked at a maximum pressure of fifty pounds to the inch, make no smoke, and travel, with its load, not less than ten miles an hour. The appearance of the advertisement elicited afresh the shafts of ridicule, as well as the strictures of practical men. Mr Nicholas Wood, in his *Treatise on Railroads*, says: 'It is far from my purpose to promulgate to the world that the ridiculous expectations, or rather professions, of the enthusiastic speculatist, will be realised, or that we shall see engines travelling at the rate of 12, 16, 18, or 20 miles an hour.'

§ III. EARLY DAYS OF THE LOCOMOTIVE.

What had been known of steam-locomotion or steam-carriages up to this period?

Excepting the machines made for Kanghi—to be hereafter mentioned—Leupold's appears to have been the earliest steam-engine applicable to locomotive purposes; but the first practical idea of applying steam-power to wheeled carriages is due to Dr Robison, by whom it was communicated to Watt in 1759. Some time afterwards the latter made a model of a high-pressure locomotive, and described its principle in his fourth patent in 1784, which, among certain improvements, specified 'a portable steam-engine, and machinery for moving wheel-carriages.' Watt, however, had doubts as to the safety of his machine, and mentioned the subject to one of his friends, Murdoch, who, three years afterwards, constructed a model of a locomotive which proved the correctness of the previous calculations. This engine was made in 1787, and was employed in that year to drive a small wagon round a room at his house at Redruth, in Cornwall. Among those who saw it was Richard Trevethick, who, in 1802, took out a patent for a similar invention. Singularly enough, a similar model was exhibited the same year at the opposite end of the kingdom, when Symington's locomotive was shewn in the house of Mr Gilbert Measom at Edinburgh. He pursued the experiment, and in 1795 worked a steam-engine on a line of turnpike-road in Lanarkshire and the adjoining county. Then followed that by Trevethick and Vivian in 1802, which ran on the Merthyr tramway, and drew a load of ten tons at the rate of five miles an hour. Slight ridges were left in the edge of the wheels and on the trams, to prevent their slipping round, and to insure a forward movement. That without this precaution there could be no adhesion or advance was an idea that long prevailed. Trevethick, who was a man of great ability, and one

to whom steam-locomotion is much indebted, afterwards made a carriage to run on common roads which combined several of the arrangements now in use. The fireplace was surrounded by water, and the waste steam blown off through the smoke-pipe to produce a draught; the cylinder was placed inside the boiler for economy of heat; and the fore-wheels were made to turn by cranks connected with the piston-rod; but with one cylinder only the motion was very irregular. This engine was exhibited on one of the roads in Lambeth in 1806, without, however, exciting more than a temporary interest. Three years previously another locomotive by Trevethick had blown up—an accident which created so much dread of high-pressure steam-carriages that a feeling of alarm arose respecting their use.

Blenkinsop, of Middleton Colliery, near Leeds, constructed a locomotive in 1811, the wheels of which were cogged and ran on toothed rails; a noisy contrivance, intended to overcome the imaginary difficulty—want of bite—but effectually preventing rapid motion by its enormous friction. The engine had two cylinders, and so far was an improvement on those which preceded it, and laboured along at five miles an hour. The Messrs Chapman came next with a new plan: a chain stretched from one end to the other along the middle of a tramway was passed once round a wheel fixed beneath the carriage; and this wheel being made to revolve by the action of machinery, its bite on the chain caused the whole to move forwards. This method involved so great an amount of friction that it was abandoned almost as soon as tried. Brunton followed in 1813 with mechanical legs and feet attached to the rear of his engine, intended by their alternate walking motion to propel it continually onwards, and prevent the slipping of the wheels on the rails. Considerable ingenuity was displayed in this contrivance, which performed well, and in certain cases might be employed with advantage, but was not well adapted to locomotive propulsion. The difficulty against which it was especially applied was soon proved to have no existence. During the same year Blackett repeated

Trevethick's experiments at Wylam, in Northumberland; and the fact was satisfactorily demonstrated that, in ordinary circumstances, and with clean rails, the adhesion between the wheel and the rail was sufficient to cause a progressive motion. It would have been proved long before had the engines and tram-plates been heavier: both were too light; and the slipping so much complained of had been an accidental, not a necessary consequence.

Meantime, George Stephenson was busy at Killingworth making and testing locomotives. In 1814 he verified the experiments of other inventors, and went beyond them all in the perfection and performance of his machinery. He took out patents in the two following years for engines that, with a load of 20 tons, and on smooth rails, would travel 5 miles an hour, and 10 miles without a load. No better result at that time was looked for. The possibility of transporting heavy goods with facility at a slow pace having been demonstrated, all that remained was to make it available. These locomotives were employed on the Stockton and Darlington Railway in 1826 for coal transport, in addition to the horses. It was no uncommon sight to see one of these engines drawing behind it a train of loaded wagons, weighing 92 tons, at the rate of 5 miles an hour. In those days steam-whistles had not yet come into use; and the firemen, to give notice of their approach after nightfall, threw up high into the air, from time to time, a shovelful of red-hot cinders, which could be seen at a considerable distance by those moving in the opposite direction. Without a load the speed of the engines was not unfrequently 15 miles an hour—a most exhilarating rate of travelling, which at that period was regarded as little less than marvellous.*

* It may be interesting, in connection with the history and proceedings of the Stockton and Darlington Company, to insert a few particulars concerning a railway veteran who has lately been taken from the active scene of labour, and who was perhaps the last survivor of the veritable pioneers of railways and locomotives. This was John Dixon of Darlington, who died 10th

Before the Liverpool and Manchester Company advertised

October 1865. He was the oldest railway engineer of his day, having been the resident engineer of the Stockton and Darlington Railway under George Stephenson; and it is singular that after executing various railways in different parts of the kingdom, Mr Dixon should return to end his days as consulting engineer to the same company, in whose service he died. His father was a colliery owner as well as a land-surveyor and colliery engineer; and from him he received that sound practical knowledge which was of especial service to him in after-life. When George Stephenson was consulted as to the construction of the Stockton and Darlington Railway, Mr Dixon was engaged to shew him certain plans and levels in his possession, and to accompany him in examining the district; a strong friendship then sprang up between them which lasted through life. During the construction of that line, Mr Dixon remained at Darlington as resident engineer; and it was during this period that the late Robert Stephenson received from him his first instruction in taking levels and surveys, and in setting out railway works. Dixon was George Stephenson's resident engineer on the Canterbury and Whitstable Railway, on which was constructed the first railway tunnel. He was resident engineer at the Manchester end of the Liverpool and Manchester Railway; and remained for some years after its completion in charge of the maintenance of way and works, and of the locomotives. After constructing the Birmingham and Derby, the Chester and Birkenhead, and the Carlisle and Whitehaven Railways, he returned to Darlington in 1845, where he remained till his death. Mr Dixon might, perhaps, have attained higher eminence, and have been more publicly known, had he been a man of more ambition; but his retiring nature led him at all times to shun publicity.

In further connection with this same historically-interesting railway, we may advert to a pleasant ceremony which took place in 1857. The Company still possessed its 'No. 1' locomotive, a piece of mechanism odd enough to look at in these advanced days, but regarded as a wonderful thing in 1825. The original chairman of the Company (Mr Edward Pease), the original engineer (Mr Dixon), and the original engine-driver (Robert Murrough), all were still living at Darlington, and all took part in the ceremony, which consisted in laying the foundation-stone of a pedestal on which the locomotive was to be placed. The engine, built by George Stephenson, had only one flue or tube through the boiler; and from one end the heated air travelled direct to the chimney at the other, the heat being so imperfectly abstracted by the water that the chimney sometimes became red-hot. The cylinders were placed perpendicularly, and all the working apparatus above the boiler; the weight of the engine was about eight tons, and its speed such that a race actually came off between it and a horsed coach, the result of which was for some time regarded as highly problematical.

their prize of £500, they sent a deputation to Killingworth to witness the working of the locomotives, with a view to the employment of a similar power on the line then in progress. Although the rails were not laid with precision, the deputation found that the locomotives had been kept at work with much regularity, drawing heavily-laden trains of wagons from the coal-pits to the ships in the Tyne. They reported in favour of locomotive power, and in accordance with their decision the advertisements appeared. The 8th of October 1829 was fixed for the trial, and on the appointed day three engines were brought forward to compete for the prize: a competition which involved much more than the winning of £500. Stephenson was there with his *Rocket*, Hackworth with the *Sanspareil*, and Braithwaite and Ericsson with the *Novelty*. The test assigned was to run a distance of 30 miles at not less than 10 miles an hour, backwards and forwards along a two-mile level near Rainhill, with a load three times the weight of the engine. The *Novelty*, after running twice along the level, was disabled by failure of the boiler-plates, and withdrawn. The *Sanspareil* traversed eight times at a speed of nearly 15 miles an hour, when it was stopped by derangement of the machinery. The *Rocket* was the only one to stand the test and satisfy the conditions. This engine travelled over the stipulated 30 miles in two hours and seven minutes nearly, with a speed at times of 29 miles an hour, and at the slowest nearly 12; in the latter case exceeding the advertised maximum, in the former tripling it. Here was a result! An achievement so surprising, so unexpected as to be almost incredible. Was it not a delusion?—had it been really accomplished?—and could it be done again?

The prize of £500 was at once awarded to the makers of the *Rocket*. Their engine was not only remarkable for its speed, but also for the contrivances by which that speed was attained. Most important among them was the introduction of tubes passing from end to end of the boiler, by means of which so great an additional surface was exposed to the radiant heat of the fire that steam was generated much more rapidly, and

a higher temperature maintained at a smaller expenditure of fuel than usual. The tubular boiler was indeed the grand fact of the experiment. Without tubes steam could never have been produced with the rapidity and heat essential to quick locomotion. In more senses than one the trial of the three locomotives in October 1829 marks an epoch. By burning coke instead of coal, the stipulated suppression of smoke was effected. The coke and water were carried in a tender attached to the engine.

On the 15th of September 1830 the railway was opened. The two great towns, with due regard to the importance of the event, made preparations for it with a spirit and liberality worthy of their wealth and enterprise. Members of the government, and distinguished individuals from various quarters, were invited to be present at the opening. On the memorable day a train was formed of eight locomotives and twenty-eight carriages, in which were seated the eminent visitors and other persons present on the occasion, to the number of 600. The *Northumbrian*, one of the most powerful of the engines, took the lead, followed by the train, which, as it rolled proudly onwards, impressed all beholders with a grand idea of the energies of art. At Parkfield, 17 miles from Manchester, a halt was made to replenish the water-tanks, when the accident occurred by which Mr Huskisson lost his life, and tempered the triumph by a general sentiment of regret. Business began the next day. The *Northumbrian* drew a train with 130 passengers from Liverpool to Manchester in one hour and fifty minutes; and before the close of the week six trains daily were regularly running on the line. The surprise and excitement already created were further increased when one of the locomotives by itself travelled the 31 miles in less than an hour. Of the thirty stage-coaches which had plied between the two towns, all but one went off the road very soon after the opening. In December commenced the transport of goods and merchandise, and afforded further cause of astonishment; for a loaded train, weighing 80 tons, was drawn by the *Planet* engine at from 12 to 16 miles an hour. In February 1831 the *Samson* accomplished a greater feat, having conveyed 164½ tons

from Liverpool to Manchester in two hours and a half, including stoppages—as much work as could have been performed by seventy horses.

The facts could not be disputed. Neither the laws of nature nor science could be brought to accord with the views of those who saw in the new agencies the elements of downfall and decay. Even the Company had gone surprisingly astray in their calculations. Believing that the major part of their business and of their revenue would be derived from the transport of heavy goods, they had set down £20,000 a year only as the estimated return from passenger traffic; and scarcely a week had passed before they became aware of the fact, as agreeable as it was unexpected, that passengers brought the greatest return.

The history of a great success cannot be otherwise than usefully illustrated by that of a comparative failure—*road locomotives*; seeing that many persons looked alike favourably on both. Du Halde relates that about the year 1700 the Jesuit missionaries in China invented certain mechanical curiosities for the entertainment of the emperor Kanghi. 'They caused a wagon to be made of light wood, about two feet long, in the middle whereof they placed a brazed vessel full of live coals, and upon them an eolipile, the wind of which issued through a little pipe upon a sort of wheel made like the sail of a windmill. This little wheel turned another with an axletree, and by that means the wagon was set a running for two hours together. The same contrivance was likewise applied to a little ship with four wheels: the eolipile was hidden in the middle of the ship, and the wind issuing out of the two small pipes filled the little sails, and made them turn around a long time.' This seems to denote a kind of hot-air engine. Some years later Cugnot produced a steam-carriage at Paris, which, after having proved its inefficiency, was laid aside, and is still to be seen in the Conservatoire des Arts et Métiers. In 1772, the American, Oliver Evans, began to experiment on steam with a view towards employing it as a substitute for animal power. Evans foresaw that steam would one day be the prime agent of

locomotion; and he frequently declared that the time would come when travellers would be conveyed on good turnpike-roads at the rate of 15 miles an hour, or 300 miles a day, by a contrivance similar to his own. Within the next thirty years numerous attempts were made by inventors in this country to employ steam-power on common roads. The prospect appeared promising; for if once successful, there were excellent highways already prepared on which to conduct a traffic. Trevethick's experiments have already been mentioned. Griffiths brought out a steam-carriage in 1821, portions of which were the invention of a foreigner. Another by Gordon, in 1822, was contrived to work inside a large iron drum, as a squirrel runs in his revolving cage; with what advantage does not appear. Gurney next took up the subject, and produced an engine, cleverly constructed, in which the objection as to noise was to a great extent overcome. Instead of allowing the waste steam to be blown off by puffs, as in the usual way, it was made to enter a chamber, from which, by a special contrivance, it issued with a steady and noiseless current, and created a draught as it passed to the funnel. In 1826 it performed the journey from London to Bath. Other competitors were in the field —Dance, Maceroni, Church, and Hancock, among the most prominent: Gurney, persevering, had in 1831 three steam-carriages running for the conveyance of passengers on the road from Cheltenham to Gloucester. Four trips a day were kept up from February to June, at a greater rate of speed than that of the stage-coaches on the same nine miles of road, and at half their fares. The success was such as might have led to a permanent undertaking, had not a formidable opposition been organised. Injurious reports were industriously circulated, and all travellers cautioned against trusting themselves to the dangers of steam; and, for more effectual hinderance, a portion of the road was designedly and mischievously covered to a depth of eighteen inches with loose stones. In attempting to pass this impediment the working-axle of the engine was broken, which for the time put a stop to steam-communication

between Cheltenham and Gloucester. Before any steps could be taken to renew it, local opposition crushed the whole enterprise. In the same year Hancock started a steam-carriage—*The Infant*—to run between Stratford and London, which excited much attention from the compactness and efficiency of its arrangements, and led to attempts in other quarters. Sanguine projectors promised lines of steam omnibuses for all the great thoroughfares of London and the suburban districts, and coaches for Bristol and Birmingham. To talk of travelling 25 miles an hour on a turnpike-road, with all its windings, all its regular and accidental traffic, was a mistake: half that speed would be the highest compatible with public safety. We may as well finish what we have to say on this subject of steam on common roads, by remarking that it is still a question whether highway locomotives might not be employed with profit and convenience between railways and towns lying a short distance off the line. At present they are confined to ponderous vehicles for dragging very heavy weights at slow speed—under rather restrictive clauses of an act passed in 1865.

§ IV. RISE OF THE GREAT COMPANIES.

THE year 1830, as we have seen, demonstrated conclusively that steam traction on railways was a triumph; whereas a further period of six and thirty years has failed to develop a commercial profit for steam on common roads.

The unquestioned success of the Liverpool and Manchester Railway revived some of the projects of earlier years. Two schemes which had been put forth for a railway from London to Birmingham were combined, the object being four lines of rail throughout the whole distance. Had this original intention been carried into effect, there is great reason to believe that the

advantages which it offered would have more than compensated for the additional cost involved in such a width of roadway. Ultimately, however, a double line of rails was decided on, and a bill brought before parliament and read a first time in 1832. Being referred to a committee, it met with a most strenuous opposition, notwithstanding which it passed the Commons, but was thrown out by the Lords. Two noblemen, whose estates lay near Watford, exerted all their powerful influence against it; and the company, for their unsuccessful attempt, were put to an expense of £32,000. They carried their point in the next session at a total cost of £72,868. Mr R. Stephenson was engaged as engineer. The original estimated cost was in round numbers £2,500,000: owing, however, to the unforeseen difficulties, to the rise in the price of iron from £9 to £14 per ton, and the panic in commercial affairs in 1836, the actual cost amounted to £2,000,000 more. The line, 112¼ miles in length, was opened for the entire distance in 1838. In 1846 the name of the line was changed to 'London and North-Western,' under which it now (1866) includes a group of railways with extensive ramifications—their united capital being at least £50,000,000, and the length of line 1300 miles.

The Grand Junction line connecting Birmingham with Liverpool afforded a rare if not the only instance of a great railway having been sanctioned by parliament without opposition. The bill was passed in 1833, and the line opened in 1837. The act for the Eastern Counties line (now transformed to Great Eastern) was obtained in 1836; a portion was opened in 1840; as far as Colchester in 1843; and the line through Cambridge to Brandon in 1845. The act for the London and South-Western passed in 1834—opened 1840: the South-Eastern in 1836—opened 1844: the Brighton in 1837—opened 1841. The short line to Blackwall was opened in 1840: the Great Northern, formerly the London and York, in 1850. According to an act passed in 1844, the line from Chester to Holyhead was to be carried across the Menai Bridge, of which we shall have to speak more in full presently. A line from Edinburgh to Dalkeith,

worked by horses, was commenced in 1826, and opened in 1831. An act of parliament was passed in 1824 for the Monkland and Kirkintilloch Railway, a line of 10 miles, which was opened for traffic in October 1826. The line was laid out by the late Mr Thomas Grainger, C.E. The Monkland line was worked by two locomotive engines built by Murdoch and Aitken of Glasgow, and worked at a pressure of 50 pounds. This line proved such a success, that another in the neighbourhood, called the Ballochney Railway, was opened in 1828. Then followed the Glasgow and Garnkirk (now a part of the Caledonian line), opened in 1831; and the Wishaw and Coltness, &c. The next Scotch lines were the Dundee and Arbroath, the Arbroath and Forfar, Edinburgh and Glasgow (opened 1842), Glasgow and Ayrshire (1843)—all of which were carried out by Messrs Grainger and Miller of Edinburgh. The Dublin and Kingstown was the first Irish line, opened in 1834; acts for some others were obtained in 1836 and 1837.

The Great Western Railway was partially opened in 1838, the expenses attending the parliamentary proceedings being no less than £89,197. Other railways in connection with the system have been opened at various dates since. As the country to be traversed presented favourable levels, Brunel, who had been appointed engineer, recommended the adoption of a broad gauge, or width between the rails of seven feet. With the exception of the Eastern Counties line, where Braithwaite had laid the rails five feet apart, the gauge on the Birmingham and all the principal lines then undertaken, was four feet eight and a half inches. This gauge—perhaps without any specific reason—had long been used in the mining districts: Stephenson adopted it on the Liverpool and Manchester line, and hence it became the standard for other lines: not that opinion was unanimous in its favour, for the Rennies among others had declared in favour of five feet prior to 1830. Brunel considered that with a seven-feet gauge he should be able to insure smooth and steady motion; the bodies of the carriages would be between and not above the wheels, as on the narrow gauge

an arrangement, by the way, not now carried out in practice. Ordinary carriages and other vehicles might be conveyed on low trucks without difficulty, owing to the increased width; and, more than all, the locomotives would be adapted for extraordinary developments of power. The increased expense excited murmurs and an inquiry, but without leading to any alteration. On the Eastern Counties line the directors had found it necessary to abandon the five-feet gauge for the narrower one universally adopted on lines with which they came into connection.

When in 1844 the line from Bristol to Gloucester was opened, which, by the influence of the Great Western Company, had been laid on the broad gauge, all the practical inconveniences of 'break of gauge' were immediately felt. Travellers from Bristol or Birmingham, compelled to pass with all their baggage from one set of carriages to another, were not slow to murmur and threaten; and at the latter-mentioned town a public meeting was held to remonstrate against a continuance of the interruption. This may be considered as the first move in the 'battle of the gauges,' which was fought with the spirit and pertinacity ever excited by a desire for gain, or the hope of circumventing an opponent. The territory lying between the two rival lines—the Great Western and the North-Western—was the prize contended for. Whichever obtained possession would be able to keep the other from any share in the traffic. Active measures were taken on both sides; and troops of engineers, surveyors, and levellers, taking possession of the ground, tasked themselves to the utmost to prepare their plans and specifications for the memorable 30th of November 1845—that date, before midnight of which the 'standing orders' required the documents to be lodged at the Board of Trade. Such a running, riding, driving and steaming, contrivance and circumvention, then took place throughout the length and breadth of the land as were never before heard of. As the evening closed in, messenger after messenger rushed into Parliament Street at headlong speed, panting with excitement, and delivered his burden of papers and parchments into the custody of the government officials. The

stir was universal, for similar documents had to be placed in the hands of every clerk of the peace of every parish across which a railway had been projected! We quote from the *Book of Days* a few illustrations of this mad 30th of November: 'In country districts, as that day approached, and on the morning of the day, coaches and four were in greater request than even at race time, galloping at full speed to the nearest railway station. On the Great Western Railway an express train was hired by the agents of one new scheme; the engine broke down, the train came to a stand-still at Maidenhead, and in this state was run into by another express train hired by the agents of a rival project; the opposite party barely escaped with their lives, but contrived to reach London at the last moment. On that eventful Sunday (for it happened that November 30th was on a Sunday in 1845) there were no fewer than ten of these express trains on the Great Western and eighteen on the Eastern Counties. One railway company was unable to deposit its plans because another company surreptitiously bought, for a high sum, twenty of the necessary sheets from the lithographic printer; and horses were killed in madly running about in search of the missing documents before the fraud was discovered. In some cases the lithographic stones were stolen; and in one instance the printer was bribed by a large sum not to finish, in proper time, the plans for a rival line. One eminent house brought over four hundred lithographic printers from Belgium; and even then, and with these, all the work ordered could not be executed. . . . . However executed, the problem was to get the documents to Whitehall before midnight on the 30th of November. Two guineas a mile were in one instance paid for post horses. One express train steamed up to London 118 miles in an hour and a half, nearly 80 miles an hour. An established company having refused an express train to the promoters of a rival line, the latter employed persons to get up a mock funeral cortége, and engage an express train to convey it to London; they did so, and the plans and sections came *in the hearse*, with solicitors and surveyors as mourners!' At the Board of Trade

the excitement became intense, as the evening of the 30th wore on. 'One agent arrived while the clock was striking twelve, and was admitted. Soon afterwards a carriage with reeking horses drove up; three agents rushed out, and finding the door closed, rang furiously at the bell; no sooner did a policeman open the door to say that the time was passed, than the agents threw their bundles of plans and sections through the half-opened door into the hall; this was not permitted, and the policeman threw the documents out into the street.' The baffled agents had lost time by being at the mercy of a post-boy who did not or would not know the nearest way from Bishopsgate station to Whitehall.

More than 1200 companies started in that year, one half of which registered their prospectuses. The capital represented by these registered schemes amounted to the stupendous sum of £560,000,000. As a result of the preliminary struggle, 600 railway bills were actually brought forward in 1846. Among other important matters, the gauge question was discussed, and the Great Western projects, after rigorous investigation, were authorised under certain conditions: at the same time a commission of scientific individuals was appointed to test the merits of the respective gauges. Many persons will remember the experiments made by Professor Barlow and the astronomer-royal in January 1846—remarkable for the extraordinary velocity at which the trial-trips on broad and narrow lines were made. Their report embraced the whole bearings of the question, the difficulties of break of gauge were fully considered, advantages and disadvantages balanced; and although in some respects the broad gauge was to be preferred, they recommended that as the greater part of England was already laid with the 4 feet 8½ gauge, it alone should be maintained and permitted 'in all public railways now under construction, or hereafter to be constructed in Great Britain.' The appearance of this report kindled a lively controversy: the Board of Trade did not hold themselves bound by all the recommendations; and permission was eventually given to the Great Western Company to extend their broad gauge to Rugby, to Birmingham, and Wolverhampton; also to

the whole south and west of their existing line from London to Bristol, but to be confined to those limits. Thus the question was compromised, and scope allowed for an active competition which still exists between the two companies most interested; although experience has at length taught them that more is to be gained by a friendly interchange of traffic than by a reckless duplication of unnecessary lines.

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§ V. ERA OF THE MENAI TUBULAR BRIDGE.

BEFORE tracing the railway history of the last twenty years, it will be desirable to notice somewhat fully the great advance in the science and mechanism of construction made by the formation of the first *tubular bridge*—the massive, costly, wholly-original *Britannia Bridge* over the Menai Strait.

To know what the passage of the Menai used to be, we will suppose a traveller going from London to Dublin at the beginning of the present century. When the coach reached Bangor it was driven down to the water's edge, where lay a lumbering old ferry-boat; and everybody dismounted and went on board, while the coachman, guard, and two or three porters unloaded the vehicle, and followed with all the baggage and parcels. Perhaps it rained or snowed, and perhaps a howling tempest added to the dismal effect of darkness—no matter; there was no shelter. Fine weather or foul, from thirty to fifty minutes were lost in this uncomfortable crossing. With the landing on the Anglesey side of the Menai, began a new series of delays while another coach was laden; and so on to Holyhead.

The Menai Strait, thus with difficulty crossed in those days, is an arm of the sea, about twelve miles in length, and in width from a few hundred yards to two miles; it washes the western extremity of Caernarvonshire, and separates it from the island

Anglesey. The tide rushes through twice a day, rising and falling about twenty feet, creating such eddies among the rocks as are dangerous to small vessels. When the union between Great Britain and Ireland was effected in 1801, numerous projects for crossing this Strait were revived. Some proposed a bridge; others, a stone-mound, a sort of huge dam with arches in it; others, a tunnel underneath. The highway itself was repaired in the course of the next few years; but so imperfectly, that some persons in Ireland being summoned on the 27th of February 1810 to appear as witnesses in the House of Commons, it was considered a hardship that they were required to present themselves by the 8th of March. Telford was instructed to prepare designs for a bridge across the Menai Strait, the want of which became every year more pressing. His first design was for a bridge of five arches at the Swilly Rocks; but he soon followed it by a second, with a single arch of 500 feet span, which offered less of obstruction to the navigation, and had his decided preference. Ultimately, however, he recommended a suspension-bridge, as best suiting all the exigencies of the case. An act of parliament having been obtained in 1818, preparations were forthwith commenced, by building barracks to lodge the workmen and labourers, and seeking out for stone suitable for the work. The level of the bridge was planned to be 100 feet above the water, with four arches on the Anglesey side, and three on the Caernarvon side, each 65 feet high and 52 feet 6 inches span. The foundation for these and for the Caernarvon main pier was laid in 1820. In 1822, the abutments and wing walls were completed; the main piers above the roadway proceeded with, and the stones carefully fastened together by iron ties and bolts, thus giving solidity to the whole mass. The height of these towers from the roadway is 53 feet, and the distance between them across the Strait 579 feet. Tunnels were excavated in the solid rock for containing the masses of iron to which the chains were to be attached. The chains, sixteen in number, were formed of flat wrought-iron bars, each 10 feet long, $3\frac{1}{4}$ inches wide, and 1 inch

thick. The next operation was the attaching of the vertical bearing-rods, and then the laying down a floor of three-inch deal-planks, coated with tar. The 30th of January 1826 was the day of opening. At half-past one o'clock, the London mail-coach passed across the estuary, at the level of 100 feet above that tideway which heretofore had presented a decisive obstruction to travellers. The bridge has bravely defied wind and weather; even the tremendous hurricanes of 1838–39, which wrought much mischief on other bridges, did no other damage than disturb two or three of the suspension-rods. And there it still hangs, notwithstanding its weight, presenting so light an appearance, that to a distant spectator its graceful curve, suspended high in air, may seem the fabled bridge of the Mussulman. Long may it stand, to commemorate the name of

> 'Telford, who o'er the vale of Cambrian Dee,
> Aloft in air, at giddy height upborne,
> Carried his navigable road, and hung,
> High over Menai's Strait, the bending bridge!'

We have noticed this beautiful bridge, which still attracts the admiration of all visitors to Bangor, somewhat fully, not because it is a railway bridge, but because of the later discussions whether it *might* be used as a railway bridge. The time soon arrived when another system had grown up, and railways, stretching their iron length north, east, west, and south, called into existence structures which, for magnitude and purpose, far surpass all that had previously been thought essential for safe and rapid travelling. If it was desirable to have quick communication with Ireland in 1825, it was not less so in 1845; there was the same barrier to overpass in the one case as in the other—the Menai Strait; and from the commencement of the Chester and Holyhead line, a work of formidable engineering difficulties, the means of crossing became of primary importance. One of the first ideas was, to bring the railway on each shore to the suspension-bridge, and convey the passengers across from one side to the other in light carriages; but who, in these days of impatient journeying, would have submitted to such a delay?

—it would have seemed like going back to the old ferry. Some persons thought rails might be laid on the bridge itself; but engineers soon decided that the structure was not suitable. The company consulted Mr Robert Stephenson, who, after a survey of the locality, recommended the building of a bridge of two arches, at a place about a mile from the suspension-bridge, towards Caernarvon, where a rock in the centre of the channel offered a good foundation for a pier; but the authorities, keeping in view the importance of unobstructed navigation, would hear of no compromise; some other scheme had, therefore, to be devised. Experience had shewn that hollow columns are stronger than solid columns; hollow beams, than solid beams. What, then, if a hollow iron beam could be made large enough for a train to pass through it, and laid across the Strait?

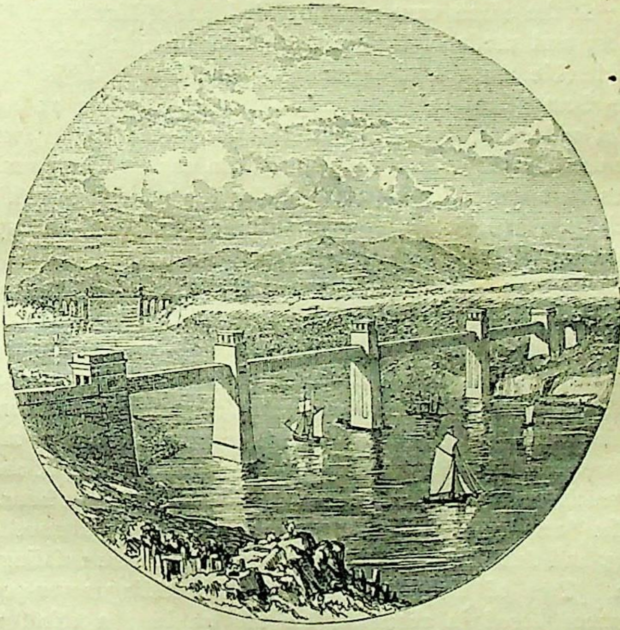
Daring as was the idea, men were found able and willing to undertake its realisation; and under Robert Stephenson's direction the experiments were commenced. The first step was to determine the best form of hollow beam, or tube. The conclusion ultimately arrived at was, that a rectangular tube, with a double top and bottom, partitioned into square cells or compartments, was the form best adapted for the purpose; and the works at the Menai Strait were begun in 1846 with an activity as fertile in resources as vigorous in execution. The Penmaen Quarries being laid under contribution, a massive abutment rose on either shore, close to the water's edge, against which the railway embankments terminate. These abutments are 62 feet 6 inches wide at their base, and taper gradually to 55 feet at the height fixed for the resting-place of the tube—100 feet above high-water. At the extremity, the masonry is carried still higher, and finished to resemble a low square tower, with two large gateways in it, which receive the ends of the tubes looking out on the Strait. The architecture is a combination of the Egyptian and Grecian styles—massive and light; and only by this adaptation is the erection saved from being an embodiment of ugliness. From the tower, a solid parapet or wing wall extends the whole length

of the abutment, and finishes in a huge pedestal, on which rests a lion, reminding one of Egyptian monuments by its colossal size. The sculpture is truly lionlike, and though couchant measures 25 feet 6 inches long, 12 feet 8 inches high, and of proportionate breadth. A single paw measures more than 2 feet across; and the entire weight of the animal is 70 tons. There are four of these lions; two at each extremity, looking down in silent majesty on the swift trains as they approach from the east or the west.

Let us suppose the abutments finished: between them flows the sea with a width of nearly 1500 feet, and how is this to be crossed? The Britannia Rock stands midway, just visible at mid-tide; it serves as a foundation for a tower. Still, the distance is too great to be passed at a single stride, and two other towers were built, one between the centre and each abutment, by which the channel is divided into four spans, two of 460 feet, and two of 230 feet. All the towers are of the same width as the abutments, and each has two openings at the level of the tube, corresponding to those left in the abutments. The Britannia Tower, so named from the rock on which it stands, is 221 feet 3 inches high, reckoning from its foundation, and 191 feet 6 inches above high-water mark. The other two towers are 18 feet and the abutments 35 feet lower than this.

All this time the work of preparing the tubes had been pushed forward with not less activity. The plan adopted was, to erect strong stages, supported by scaffolding, across the comparatively short space of 230 feet between the abutments and shore-towers on either side, on which those portions of the tubes might be built in the places they were to occupy when finished. These stages were made sufficiently strong to bear a weight of 2000 tons—more than 100,000 cubic feet of timber and 32 tons of iron bolts having been used in their construction. For the central tubes, those which were to stretch across the 460 feet span to the Britannia Tower, another method was employed: they were to be built near the water's edge, and afterwards lifted into their place. A stage was, therefore, constructed on the

Caernarvonshire shore, not far from the bridge, large enough for the purpose, 2200 feet in length, and nearly 39 feet in width. On this, at the proper distances, strong timbers were erected to support the tubes; so that the workmen might be able to move about underneath them during their construction. A tramway was laid down from end to end, to facilitate the transport



Menai Tubular Bridge.

of materials; and when all the rivet-making machines, punching-machines, and shearing-machines were in full work, the place might have been deemed the head-quarters of all the smiths of a province. Two fire-engines and large tanks of water were kept in constant readiness in case of fire. A village with shops, a school, and a surgery sprang up; and the place became the

temporary abode of numerous artificers and labourers, with th wives and families.

The tubes are 472 feet long, 14 feet 8 inches extreme wid 30 feet high at the end which rests on the Britannia Tow and 27 feet at the other; the difference being made to give true parabolic curve to the top, while the bottom is straig One of them was contracted for by Messrs Garforth of Duk field; all the others were made by Mr Mare of Blackwall. T process and mode of their construction brought into play considerable amount of ingenuity. The iron used is boil plate, from 3-8ths to 3-4ths of an inch thick, from 21 to inches wide, and from 6 to 12 feet long—the largest, whi were used for the bottom, weighing 7 cwts. each. These vario plates were sorted, and passed under the punching-machin which punched holes through them at the rate of forty minute, as though iron were as soft as dough. When t plates left the machines, they had a row of holes 3-4ths an inch diameter, and 4 inches apart, along each edge; a being laid side by side, 'covering-plates,' also punched, we placed over each joint, and the whole firmly riveted togethe The rivets were all made on the spot, from ¾-inch rod-iron, which such a quantity was used as would measure 126 mile and weigh about 900 tons. A man and boy working at one the machines could produce from 400 to 600 rivets per hour.

The 'sets' of plates were afterwards lifted by a travellin crane, and delivered over to the riveters who were building t tube. Two of these sons of Vulcan, wielding seven-pou hammers, stood in readiness on the outside; a third, 't holder-up,' armed with a thirty-pound hammer, lay in t inside; and each had an attendant imp, in the shape of a nimb grimy-faced boy. The plates being held up, one of the bo took a red-hot rivet from the furnace that stood close by, a tossed it over to the inside, where it was picked up by anot boy, who dexterously thrusting it into the hole intended to r ceive it, the holder-up immediately held his long-handled ham firmly against it, while the two on the outside, falling to w

might and main, battered away until the rivet had got an outside as well as an inside head, which they 'swaged' into a true form. What their hammers had failed to do, was then done by the rivets—namely, pulling the plates perfectly close together by the shrinking of the metal in cooling. The sides of the tubes, within and without, have a columnar appearance, produced by the riveting on at regular distances of what is called T iron, running from top to bottom both inside and outside. These lengths of T iron cover the joints of the plates, and are secured by a double row of rivets. The top and bottom are cellular—that is, they are double, with compartments running lengthwise from one end to the other. The double top is a space of 21 inches high partitioned into eight square passages or 'cells;' the iron partitions, kept in place by the angle-iron, run from end to end; and the whole being firmly riveted together, the important object is realised—the greatest possible strength with the least possible weight. The bottom of the tube has six cells only, put together in such a way as to resist the strain. Hence the larger plates in the bottom, so that the number of joints may be as few as possible. Besides all these precautions, thirty-six strong frames of cast iron are fitted inside, at regular distances, throughout the entire length, and triangular plates of iron, called 'gusset-pieces,' are riveted in at the corners above and below, for the purpose of still further stiffening the tubes. The calculation now is, that the tubes will resist five times the pressure of the heaviest gale.

On the 5th March 1849, Mr Stephenson drove and clinched the last rivet. Never before had such a scene of riveting occurred in the world as these tubes exhibited; there were 2,000,000 rivets altogether, and each required about a dozen blows from ponderous hammers. Then came the formidable task of floating out the two great tubes, each weighing 1800 tons, to the middle of the Strait. First, eight docks were dug under each tube, large enough to receive a pontoon or flat-bottomed barge 98 feet long, 25 feet wide, and 11 feet deep. There was a barge for every dock, each one fitted with valves

in the bottom, made to open or close at pleasure, and pumps for the admission of water by the valves. Each b introduced into its dock, the valves were opened, to prevent rising and falling of the barges with the tide until their serv were required. Powerful capstans were fixed on either sh at the foot of the towers, and some on the decks of the p toons; and buoys were moored across the channel, to supp the two miles of four-inch hawsers prepared for the haul besides numerous ropes to serve as checks and guides dur the operation. Each of the capstans had a superintend with a division of labourers under him, besides sailors carpenters who were to give their services in case of ne Each pontoon had a numerous crew. Altogether, about 6 persons were engaged in the great operation. Ample store provided, too, of spare ropes, lines, hawsers, and all ot materials required for the movement and control of so unwie a mass. The distance which the tube had to float was ab 1600 feet; and as the various points of operation were far ap a system of flag-signals was organised.

The news had gone abroad, that on the 19th of June 18 the first tube would be floated; and spectators came from quarters to witness the operation. At low-water, the valves the pontoons had all been shut, in readiness for the approachi event. As the tide rose, the vessels rose with it, until th decks touched the bottom of the tube. At first no effect observed; but higher and higher swelled the stream, bear up the great barges; a few inches more, and a small open became visible between the iron and the wood; gradually widened, and then from mouth to mouth among those stood by were spoken the words 'She's afloat!' and fr mouth to mouth they went, spreading the gratifying intellige among all onlookers. The capstans were at once set to wo Slowly the great tube moved away from the shore. Stephen (with Brunel and Locke as volunteer lieutenants) conveyed orders by movements of his arms; and they, exhibiting sig as agreed on beforehand, kept the huge bulk perfectly un

control in the most suitable positions. Now came a sore trial of the patience of all. Suddenly one of the capstans gave way, torn from its place by the great strain upon it, and the excitement of the men running round at the bars. This accident deranged the whole proceeding; and there was no alternative but to haul the tube back to its moorings. The attempt was renewed on the following day, the 20th, and succeeded after numberless difficulties. The tube was brought one end to the Britannia Tower and one to the Anglesey Pier; and the arrangements had been so nicely calculated, that the time for this critical operation fell exactly at slack-water, when the pause in the tide-stream rendered the various evolutions easily practicable. Erelong the tide turned; the valves in the pontoons were opened, and their buoyancy diminishing as the water entered, they fell gradually with the stream, and left the tube resting on a projecting shelf made to receive it near the base of the piers. It was thus left until August, while preparations were made for the raising. It was already a bridge; but from where it lay near the water, it had to be lifted up 100 feet. Though but a part of the whole undertaking, this was in itself a task requiring means and appliances of stupendous order. Let any one imagine 1800 tons of iron lying in a mass at the foot of an ordinary church-tower, to be raised to the summit!

For such an extraordinary weight, extraordinary means must be used, and yet the means appear small when compared with the end to be accomplished. By the aid of three hydraulic presses, adequate in strength and dimensions to the enormous weight to be lifted, the tube was raised into its place. Two were placed side by side on the Britannia Tower. In these the plunger or 'ram' was eighteen inches diameter. The other was of larger dimensions—a very giant among hydraulic-presses; the cylinder was nearly 11 feet long, with sides 11 inches thick, and 20 inches diameter inside. It was cast all in one piece, and weighed 17 tons, to which the weight of the ram and other fittings added about 22 tons more. The water was forced in by a forty-horse steam-engine, through a hole not more than half an

inch in diameter; and so prodigious was the pressure, that h an outlet been made, the fluid would have spouted up t height of 20,000 feet—theoretically, at least, in accordance w hydrodynamic principles. Between the presses and the Me was a height of 140 feet; the lifting-power was communica through this space by means of massive chains, two of wh were made fast by their lower extremities to each end of t tube, while the upper extremities were secured to a 'cross-hea on the top of the rams. The steam-engines forced water into t presses; slowly the rams rose, bearing up the chains and t tube, which hung far beneath. This was another anxio moment, when the ponderous structure swung clear off its su port, borne only by the chains; but the machinery held, an inch by inch, the rams emerged from the cylinders, until, in h an hour, they were at their full height—six feet. This was the 11th of August. As the tube rose, beams and balks timber were carefully built up beneath it, to afford support i case of accident. The lifting was by a series of pumpings, s feet at a time. But a mishap occurred. On the 17th, the pile up wall was thirty feet above the water, when suddenly the was a crash, followed by a heavy fall. The great cylinder ha burst; and the tube, no longer supported, fell, but only for few inches, the timber-wall being there to receive it. That ca iron, eleven inches thick, should have been burst by such cause, furnishes a striking instance of the amazing pressure the water. In six weeks, a new cylinder was cast, after whi the lifting went on, six feet a day, without further accident. I the 13th of October it was up to the required level. Thr cast-iron key-beams were immediately thrust across the recess each end, and on these the tube finally rested.

The first tube being thus happily disposed of, preparatio were forthwith commenced for pursuing the important wor The floating and raising of the other three tubes were l repetitions of what we have here described: the second was up in December of the same year; the third in June, and t fourth in August, 1850. The tubes, when in place, were unit

so as to form a continuous length from one side of the Strait to the other; but to allow for the expansion and contraction of the tubes in hot and cold weather, there were 264 cast-iron rollers and 132 gun-metal balls inserted beneath them, working in frames and channels; on these the great tubes have free movement, and the phenomena of expansion and contraction which they exhibit are very remarkable. In the hottest part of the summer they are twelve inches longer than in the winter—a difference which, had they been fixed, would have thrown down the solid piers by a resistless alternating pull and thrust.

The lifting of the second tube into its place in December 1849, established a communication between the two shores; and not to lose time, while the other portions of the works were advancing towards completion, preparations were at once made for running trains through the finished tube. Rails were laid down on longitudinal sleepers of pine, running from end to end of the tube; and as soon as the necessary fittings in the towers and at the abutments were perfected, a trial was made of the strength of the tube. On the 5th of March 1850, Mr Stephenson, accompanied by his staff, left Bangor Station with a train of three engines for the Britannia Bridge. They slowly entered the tube, and coming to a pause in the centre of each span between the towers, the train was left standing for a time, to try the effect of its weight. This was followed by a severer test, in the shape of twenty-four heavily laden coal-trucks, making altogether a load of 300 tons, which were drawn into the middle of the Caernarvon tube, and left for two hours; even in this instance the deflection was not more than 4-10ths of an inch—an amount too small for consideration. Afterwards a still heavier train was sent through: to the twenty-four coal-trucks were attached as many more laden with coke, besides a number of carriages containing about 800 passengers—all passed slowly through, and the Britannia Bridge was opened.

Visitors to the Menai Strait, on mounting to the top of one of the tubes for a survey of the Britannia Bridge, and the prospect it commands, find themselves on a long platform, nearly 15 feet

in width. Running parallel with it, at a distance of nine fee the other tube, the top of which presents a similar platfo and as the lintels in the openings through the towers are h enough to be out of the way, it is possible to walk from one e to the other without interruption. In the interior, a pathway planks is laid throughout, and there is ample room to stand either side during the passage of a train. A sombre light admitted through a series of circular holes, 4 inches diamet which are pierced through the side-plates on one side of t tube, at intervals of 12 feet, and glazed with plate-glass.

Compared with the suspension-bridge, the stone and iron the Britannia Bridge are as 15 to 1. The entire length of t bridge, at the level of the railway, is 1841 feet, and of the tub 1513 feet; the total weight of iron is nearly 12,000 tons— which the two tubes contain 9360 tons of wrought iron, 10 tons of cast iron, and 175 of permanent railway. In th fabrication, 186,000 separate pieces of iron are used, pierc with 7,000,000 holes, put together with more than 2,000,0 rivets, and strengthened with 83 miles of angle iron. masonry, including stone, brickwork, and rubble, there a 1,492,151 cubic feet, or 104,875 tons, all of which, number 2177 cargoes, was built up and finished in two years and m months. The scaffolds were, in themselves, marvels of co struction; 175,000 cubic feet of timber were used in th erection; and adding that used for the platforms on which t tubes were built, the total was 403,335 feet. For many mont the outlay in wages was £6000 a week; and the cost for t whole of the works more than £600,000. The developme and formation of railways had called into existence means a appliances unknown when Telford built his suspension-brid and no sooner did an unexpected difficulty occur, than so ingenious individual was found ready to overcome it. The ir manufacture, especially, seemed endowed with new energ and by producing rolled plates larger than ever before, made riveted tube possible. If a new tool or machine was needed effect a certain purpose, it was always forthcoming—created

the very necessity; and now these inventions all remain as so much gain to the power of handicraft.

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§ VI. RECENT HISTORY OF RAILWAYS.

WHO can glance, without a sentiment of wonder, at the spread of the railway system in the last twenty years, since the Menai tubular bridge was first discussed? The statistics connected with the matter have become almost unmanageable for their vastness. After the spasmodic years 1845 and 1846, a dull reaction marked 1847 and 1848; and then the excitement began again in 1849. According to the Report of the Commissioners of Railways for 1850, the additional lines opened in that year made the total for the United Kingdom 6621 miles. Up to December 1850 the lines authorised by parliament comprehended 12,182 miles. The whole number of stations was 2030; the number of engines at work was 2436; the miles travelled over 40,161,850, or 110,333 per day; the tons of coke burnt, 627,528, which had been produced from 896,466 tons of coal. The whole number of passengers exceeded 60,000,000; and the grand total cost of all the railways amounted to £220,000,000.

The year 1851 presented fifty-nine new Acts of Parliament relating to railways; not, except in a few cases, for the construction of important new lines; but rather for amending and enlarging lines already sanctioned. The battle of the gauges was still continued, the North-Western and Great-Western fighting each other at all points. The Great-Northern had become a formidable competitor to all its neighbours, abstracting traffic from the Eastern Counties, the Midland, and the North-Western by reason of the directness of its course. Many of the new lines opened brought very poor receipts, bringing down the averages much below their former level. Thus the receipts per mile per week fell from £66 in 1845 to £43 in 1850. This was partly due to

the fact that passengers had begun to travel by third class mo and more largely, instead of paying second-class fare. In 18 the last year before the *compulsory* Parliamentary trains, th third-class passengers were only 40 per cent. of the whol whereas in 1850 they were 52 per cent. Another cause diminution in average receipts was the opening of many bran lines, which seldom pay so well as through or main lines. was found, on comparing several preceding years with 1851, th the average charge for a ton of goods was just about equal p mile to the average charge for a passenger. Two other stea averages were noticed—viz., that the average length of journeys did not depart far from seventeen miles, in any o year; and the average fare two shillings. Another poi ascertained pretty accurately in 1851, was the large amount *dead weight* involved in most passenger trains. If nine carria on a narrow-gauge line carried 190 passengers, it was calculat that 1440 cwts. were employed in carrying 288 cwts. A Gre Western express train often employed 1440 cwts. in drawing o 182 cwts. So great is the pressure thus exerted on the pe manent way, that it was calculated that one mile of double li on the broad guage had 400 loads of timber and 5000 cwts. iron to make a way stout enough to bear the burden.

Year after year the system spread, with a rapidity which need not study in detail. In 1852, there were 52 railway a passed; in 1853, they reached so high as 102; they fell to in 1854, and to 77 in 1855. In 1856 there were only 60 r way acts; but they made a start upwards to 84 in 1857. Th descended a little to 75 in 1858; but rose to 105 in 1859, 120 in 1860. The railways open for traffic in the United Ki dom at the end of 1860 were 10,433 miles; they employ 5801 locomotives, 15,076 passenger carriages, and 180, goods and mineral wagons. In round numbers, the railw carried 163 million passengers, 30 million tons of general m chandise, 51 million tons of coal and other minerals, 12 milli head of live-stock. The money received was £3,300,000 f first-class passengers; £4,000,000 for second-class; £4,700,0

for third-class; £250,000 for season tickets; £1,020,000 for luggage, parcels, horses, and dogs; £400,000 for mails; and £14,700,000 for goods, minerals, and live-stock. The trains travelled 107,000,000 miles in the year. The total expenditure for working, accidents, rates, taxes, duty, &c., amounted to £13,200,000, or 48 per cent. of the total receipts, leaving 52 per cent. for dividend on shares and interest on loans.

The extension of railways since 1860, as measured by the number of Railway Acts passed, has been amazing: no fewer than 916 Railway Acts having been passed in five years. And many of these are for very costly undertakings—such as the extension of the Chatham and Dover Railway to Ludgate Hill and Farringdon Street, the formation of two grand termini for the South-Eastern at Cannon Street and Charing Cross, the bringing of the North London to Broad Street, the penetrating through miles of streets in London by the Metropolitan system, the extension of the Great Eastern system to Liverpool Street, the formation of a great terminus and dépôt for the Midland at Somers Town, and the building of great central stations in Liverpool, Leeds, Carlisle, and elsewhere. In the year 1864, there were open for traffic 12,789 miles of railway. The capital authorised was £390,000,000 in shares, and £130,000,000 in loans; of which there had been raised and spent £319,000,000 in shares, and £106,000,000 in loans. There were carried in the year 28 million first-class passengers, 65 million second-class, and 136 million third-class, or 229 million altogether. The money received was no less than *thirty-four millions* sterling, of which the passengers paid fourteen millions, the goods and minerals seventeen millions and a half, while parcels, mails, live-stock, &c., provided the remaining two millions and a half. The average pay for each passenger was 1*s.* 2½*d.*, for each ton of merchandise 6*s.* 6*d.*, and for each ton of minerals 1*s.* 8*d.* There were about three million passenger trains, which ran 66 million miles; and two million goods trains, which ran 63 million miles. All the trains, one with another, ran 26 miles each on an average. There were 7203 locomotives, 23,471

passenger carriages, and 212,916 wagons of all sorts—a marvellous rolling-stock, certainly, shewing how great was the carrying-power of the companies.

Although we cannot give the real figures for 1866, sufficient is known of the railway traffic of the United Kingdom to warrant the estimate of £40,000,000 for the gross receipts of the year, earned upon 13,000 miles of line—exclusive of certain railways which are very little more than colliery tramways. This is about £3000 per mile per annum.

Every one knows that the cost of obtaining Railway Acts in Parliament is enormous; but none except those immediately concerned are aware how truly formidable the amount frequently is. If we take together the legal, engineering, and parliamentary expenses, for services which are all irrespective of the money paid for land or works, we come to astounding totals. In 1855, it was ascertained that 160 companies had spent in this way a sum of money which, averaged equally among them, would amount to £88,000 each. The speculative companies tend frightfully to increase these preliminary and often futile expenses. The reckless endeavours of the South-Eastern and the Chatham and Dover Companies, in 1864, 1865, and 1866, to obtain permission to make a new railway to Brighton, and the opposition of the old Brighton Company to these endeavours, cannot have involved much less than £200,000 legal and parliamentary expenses—a burden to be ultimately borne by the travelling public. All admit that railway legislation is susceptible of much amendment: there is no good reason why enormous expenses should be incurred in carrying a bill through parliament—expenses injurious alike to the companies and the public. The placing of railways under the control of the Board of Trade in 1840 was a step, but not far enough, in the right direction. The Board are empowered to forbid the opening of any line which they may consider unsafe, and to compel such alterations as public safety requires, particularly with respect to bridges, viaducts, or crossings. They can order returns of all accidents that take place, and institute inquiry according

circumstances. Then, in 1844, an act was passed designed to protect the public against the consequences of monopoly on the part of railway companies. By its provisions, government was enabled to revise the tolls and charges of any railway of which, twenty-one years after the passing of the act, the profits should exceed 10 per cent., and reduce them to this value. Further, for the protection and benefit of travellers, all companies sanctioned in 1844, or in any subsequent session, were to provide third-class carriages, and the trains provided with such carriages were placed under certain rules in regard to times, speed, stoppages, luggage, &c. In certain cases the companies have been allowed to change some of these regulations for others, but not less suitable or efficient. As regards the fare the statute is imperative; it is not to exceed a penny a mile (third class), though it may be lower. No toll is levied on third-class fares, but on all other sums received for passenger traffic, 5 per cent. must be paid to government. The act also regulates the charges for the conveyance of troops, police, and persons employed in the public service. All companies are further bound to permit the erection of an electric telegraph along their lines if required for Her Majesty's service; and compensation for loss of life or injury while travelling is substituted for the law of deodand which formerly prevailed. And lastly, paid inspectors are appointed to see that the provisions of the act are duly enforced and obeyed.

Had it not been for the regulations affecting third-class passengers, that large section of the travelling community would, we may believe, have found themselves too often still riding in open boxes, exposed to all weather, obliged to start at hours expressly chosen for their inconvenience, and delayed on the journey as might suit the humour of their carriers. Even for some years after the act was passed, there was too much disposition to shew small consideration to those who paid but a penny a mile. At many stations the second and third class passengers were often drawn beyond the shelter of the roof before the train stopped, whatever was the weather; and the

'through' transit was also rendered difficult to those who pa the lowest fares. On some lines of railway—several even whi had termini in London—open uncovered boxes were still us as third-class carriages. These were at least bearable in fi warm weather; but in winter, or during cold rains or win an unsheltered journey became most painfully distressing. O one or two other main lines leading directly from the metr polis the third-class carriages were bad, and the second-cla not much better; too low to allow passengers to sit uprig with comfort, and with a single opening of fifteen or eighte inches square on each side for all outlook and ventilation, a though not to see the country made travelling more agreeab Competition, has, however, done much towards amending the grievances; and now it is felt that the best accommodati attracts most traffic. The Great Northern was the first of t chief companies to set a praiseworthy example of what can b done with clean, convenient, and cheerful carriages; and oth companies have seen the wisdom of following in the sa course. Still, however, much more is needed.

The locomotive was so beautiful an engine, even when fi introduced on the Liverpool and Manchester Railway, that it h not undergone so many improvements as some other parts the railway system. We must not believe, however, that t uniformity prevails so much in the working details as in t simple principles; the improvements in detail have bee immense. Stephenson's prize-engine, the *Rocket*, weighed tons: locomotives now weigh from 30 to 40 tons. In how this mighty agent of travel had been improved, was first shew in the Great Exhibition of 1851, where at one side stood a ro of ponderous and magnificent locomotives, finished, though huge, with the precision of a watch, and seeming formidable their silence. The *Liverpool*, exhibited by the North-Wester Company, was one of Crampton's patent—that is, with t driving-wheels at the rear instead of at the centre. It weighe 37 tons, and had a heating-surface of 2400 square feet. Th *Lord of the Isles*, belonging to the Great Western Company, w

a favourable specimen of the ordinary engines used on the broad-gauge lines. Its weight was 35 tons, that of the tender when loaded with a ton and a half of coke and 1600 gallons of water, 18 tons—altogether 53 tons; the heating-surface was 1815 feet, with strength sufficient to bear a pressure of 120 lbs. to the inch. This engine is said to have drawn 120 tons at sixty miles an hour; the usual speed was, however, for goods traffic, twenty-nine miles an hour with 90 tons, and a consumption of 21 lbs. of coke to the mile. Besides these, there was a locomotive by Hawthorn, with improved springs, which kept the bearing on the wheels at all times equal, a steam-chamber inside instead of outside the boiler, and considered equal to a speed of eighty miles an hour. There have been many and varied improvements in the fifteen years since that great display. Wonderful, indeed, are the capabilities of recently-constructed locomotives; their velocity of at times seventy or eighty miles an hour may be increased when stronger materials or modes of construction shall be discovered. A cannon-ball in its swiftest flight travels four times faster only than the seventy-miles-an-hour express train. The phenomena of passing objects observed during such rapid locomotion are most remarkable; the steam fills and leaves the cylinder twenty times in a second; twenty times in a second the piston advances and returns, and the outblow of steam sounds as a continuous whiz, so inappreciable are the intervals between the rapid strokes. The driving-wheels, eight feet in diameter, revolve five times in a second, and at every beating of a clock the mighty engine dashes over thirty-five yards of ground! The establishment of underground railways, where engine smoke and products of combustion would prove a great nuisance, has led to the invention of locomotives which will 'consume their own smoke:' the products of combustion are carried into a spare tank beneath the engine; and the contaminated water in this tank is drawn off at intervals.

Enlarged experience has improved the details of railway construction, and has made available many aids and appliances of which the need had not been foreseen. The old 'fish-bellied'

rail has been discarded for one straight and heavier; thirty-f pounds to the yard being too light for the increasing weigh traffic, seventy-five pounds to the yard is that now most in u Taking the miles of railway in round numbers at 13,000, weight of iron laid down in rails alone would thus amount 7000 million lbs.; in the manufacture of which, as well as of iron chairs, switches, girders, and columns brought into use railway constructions, thousands of hands have been employ and the metallic branch of our national industry largely de loped. Steel rails are now used instead of iron, for very hea traffic. Balks of wood are found preferable to blocks of sto as sleepers; improved chairs, and the substitution of hollo wrought iron wedges for those of compressed wood, facilit the laying, and increase the stability of the rails; and in so instances the rails are fixed to iron sleepers by a contrivan that dispenses with the use of chairs or other intermedi support. Signals, crossings, turn-tables, all are improved— most instances substituting the simple for the complex.

Experiment has furnished data on which the frictional a atmospheric resistances to a train in motion may be calculate and the most economical principles deduced. Many interesti facts have been brought to light illustrative of the laws whi regulate weight at high velocities, and of those affecting spe by departure from a true level. The chemist, too, has lent i aid, in shewing how to remove, at stated intervals, the incru tation deposited by the water on the inside of boilers, where accumulation would be a source of positive injury and loss power. In short, every part of the railway system has unde gone, and is undergoing, improvement.

§ VII. FOREIGN AND COLONIAL RAILWAYS.

FOREIGN nations, as may readily be supposed, were eager to avail themselves of the wonderful advantages which railways were found to confer on commerce and the social arrangements of mankind. A glance at the chief countries abroad will enable us to see how far this has extended.

France.—Railways in France date from 1783, when a line was laid down at the Creusot Foundries, near Mont Cenis. Short lines were subsequently brought into operation in other quarters; but it was not until 1835 that the great movement was commenced by the authorisation of the railway from Paris to St Germains, which was completed in 1837. In the following year the Orleans line was undertaken by a company, whose resources proving unequal to the task, the government granted them a lease of ninety-nine years, with interest guaranteed at 4 per cent. Other companies meanwhile were discussing other projects: the line from Paris to Rouen was opened in May 1843, and shortly afterwards extended to Havre. More comprehensive measures followed on the part of the government, by which they proposed to form railways from the capital to all the frontiers of France, taking the principal towns and cities on the route. There were 1800 miles finished and in operation in 1851, and 1200 more in progress; railway communication was also nearly complete between several points on the English Channel and the Mediterranean at Marseilles; while by another main line Bordeaux and Bayonne were reached. The French railways commenced, and in great part open, in 1856, were computed at 7140 miles. In 1866, the network is such as to bring most of the great towns into connection with Paris—Calais, Boulogne, Amiens, Dieppe, Havre, Rouen, Cherbourg, Caen, Rheims, Lille, Douai, Arras, St Omer, on the north; Chalons, Verdun, Metz, Nancy, Strasburg, Mulhause, Besançon, on the east; St

Malo, Brest, Nantes, Alençon, Orleans, Blois, Tours, Roch Rochfort, Bordeaux, Bayonne, Pau, Angoulême, Limo Poitiers, on the west; Auxerre, Nevers, Dijon, Maçon, Ly Grenoble, Valence, Toulouse, Nice, Toulon, Marseilles, Avig Nismes, Montpellier, Narbonne, Perpignan, on the south—all now placed in railway communication with the capital, indirectly with each other. It was computed that at the end 1865 the French railways open for traffic extended to ab 8470 miles. The amount received for traffic was ab £23,000,000. The French railways are mostly grouped un six great systems or companies, known as the Northern, Easte Western, Southern, Orleans, and Lyons-Mediterranean. T dividends are larger than on the average of English lines.

Belgium.—Belgium made preparations for railways in 18 Though but a small territory, it is well situated for travel. Tw main lines were planned—from Ostend to Liege, and fro Antwerp to Valenciennes; thus touching the French fron on one side and the Prussian on the other, and intersecting Malines. 'The undertaking,' so reported the minister of pub works, 'is regarded by the Belgian government as an establi ment which should neither be a burden nor a source of rever and requiring merely that it should cover its own expenses, c sisting of the charge for maintenance and repairs, with a furt sum for the interest and gradual redemption of the inves capital.' Portions of the lines were opened in 1836; and t whole system was complete by 1841. Besides the lines belo ing to the government, however, there are others undertaken private companies, of which the Great Luxembourg is the m important: the route is from near Charleroi to Strasburg, a d tance of 140 miles. By the year 1856, the length construc and constructing reached 1120 miles. In 1866, the network almost as close and intricate as that in our own counties Lancashire and Yorkshire, so proximate are the busy towns villages. Ostend, Bruges, Ghent, Brussels, Termonde, Mech Antwerp, Tournay, Courtray, Tourcoing, Quiveron, Jemapp Mons, Charleroi, Namur, Louvain, Liege, Verviers, Ypr

Jurbise, Luxembourg, Nivelles—all within an area less than one-eighth that of Great Britain. We may mention Brussels, the capital of Belgium, as being among the few cities which have what may be called a metropolitan line extending from the terminus of one company to that of another, and accommodating intervening streets and districts of the town. It is analogous on a humble scale to the Underground Railway in London.

Germany.—Germany early permitted railways to cross her frontiers, and soon numerous lines were stretching far and wide throughout the empire. The traveller may now journey by rail from Ostend or Antwerp, Rotterdam or Hamburg, to the ports in the Baltic—to Posen, Warsaw, or Vienna, or from the Baltic to the Adriatic at Trieste. Once at Ostend, he will find an iron highway to Berlin or Basle, Prague, Munich, or Pesth, from whence a line stretches onward to Belgrade on the Turkish frontier. In short, a glance at the railway map of the continent will serve to shew how town to town and country to country are linked together from one end of Europe to the other; and still new lines are projected. In Germany the natural level of the soil is followed as much as possible, in order to avoid the expense of cuttings, embankments, or viaducts; single lines with sidings, and from four to five trains daily, at a slow rate of speed, are found sufficient for the traffic; and the scale of fares is low. The number of miles of railway open in Germany in 1851 was 4500; the cost had then been £13,000 per mile, about half that of the French lines. By 1856, the length constructed and constructing—taking Germany in its widest sense—was computed at no less than 8080 miles; including, however, the Lombardo-Venetian lines, which geographically are in Italy. What the length has augmented to in 1866 it is difficult to say; for there is much confusion between German miles and English miles in the lengths attributed to German railways. Suffice to say, that from Lemberg and Gross Wardein in the east to Cologne and Strasburg in the west, from Konigsberg and Hamburg in the north to Botzen and Trieste in the south, almost every Prussian, German, and Austrian town of any note is

accommodated with railways. The war of 1866 will per change the current acceptation of the word 'German;' but railways will remain, let the designations be what they may.

Russia.—In Russia a vast system of railways is being car out at the expense of the state. A line of 400 miles conn Petersburg with Moscow, and another of 700 miles with Wars From Warsaw to Cracow a line of 168 miles is opened; an goods-line of 105 miles, worked by horses, from the Don to Wolga. There is also a short line extending a few m from St Petersburg, chiefly for pleasure traffic, besides others Southern Russia from Kiev to Odessa, and in other directio The journey from St Petersburg to Trieste is remarkable its length, and interesting in the rapid change of latitude wh it will effect. Leaving the Russian metropolis shivering un intense frost, the traveller finds himself in the short space three days transported to the sunny shores of the Adri The 400 miles from St Petersburg to Moscow take 24 ho by ordinary train; the 700 miles to Warsaw require 35 ho the 560 miles to the Prussian frontier on the road to Berlin hours; and then the further distance to the principal Pruss German, and Austrian cities render the 'through' journeys formidable affairs—such, indeed, as could be understood in vast regions of America, but not in England. The 'Gr Russia Railway Company,' with a capital of £24,000,0 guaranteed 5 per cent. by the state, executes most of the lines

Sweden and Denmark.—The Scandinavian kingdoms h not effected very much in the construction of railways; but t are advancing. Sweden and Norway have more difficulties contend with in this matter than Denmark, on account of obstructions furnished by mountains and lakes. The year 1 presents us with the Schleswig-Holstein Railway, from Alt to Glückstadt, Kiel, Rendsburg, Schleswig, Tœnning, Flensburg, to Hadersleben; the Copenhagen and Corsöer R way; and other lines from Copenhagen to Elsinore, Aarhuus Skiva, Trondjem to Heimdal and Storen, Christiania to Li troma and Kongsvinger, Stockholm to Malmö, and seve

between towns and villages, the very names of which are hardly known in England. The war of 1865 robbed Denmark of some of her best railways in Schleswig-Holstein.

Holland.—Holland is so flat a country, and the towns are so near together, that there were many temptations for a network of railways. The railways are, in fact, very numerous, relatively to the area of the country. In 1856, the length was only 210 miles, constructed and constructing; but now they are so numerous, as to link together nearly all the towns worthy of note—such as the Hague, Dort, Breda, Rotterdam, Haarlem, Amsterdam, Utrecht, Arnheim, and Nymegen; while other railways are in progress in various directions, crossing the frontiers to Hanover, Prussia, and Belgium.

Switzerland.—This small republic, bravely confronting her own mountains, claimed credit for 200 miles of railway in 1856. She has added to the length since, by connecting Basle, Schaffhausen, Constance, Brugg, Zurich, Lucerne, St Gall, Glarus, Zug, Berne, Thun, Freiburg, Geneva, and Martigny; and bold projects are under consideration for crossing the Alps at one or two favourable points.

Italy.—The garden of Southern Europe is making progress with railways. A line from Venice to Milan, another from Turin to Genoa, and a third from Leghorn to Florence, with branches to other towns in Tuscany, made up the list so far as completed in 1851; but the subsequent period of fifteen years—despite the uncommercial, unprogressive tendency of the Papal States—has witnessed considerable advance. The formation of the Kingdom of Italy in 1860, by the transfer of so large a portion of territory to the rule of Victor Emmanuel, has given a great impetus to the construction of railways in that beautiful but so long misgoverned country. About 1320 miles were open or under construction in 1856. At present, the great cities are rapidly becoming linked together by railways. From Susa, near Mont Cenis, to Venice, there is a continuous rail, passing through Turin, Magenta, Milan, Bergamo, Brescia, Verona, and Vicenza, with eight or nine small branches out

northward towards Switzerland and the Tyrol. Turin also s off lines to Pinerolo, Cuneo, Fossano, Genoa, Alessandria, Pavia. Then, Milan is a starting-point for a grand extending through Lodi, Piacenza, Parma, Modena, Bol Ravenna, Rimini, Ancona, and Trani to Otranto, at the 'heel of the boot.' On the western side of the peninsula are continuous lines of rail carrying the passenger on and to Spezzia, Lucca, Pistoja, Pisa, Leghorn, Florence, Sie Rome, Capua, and Naples. What names these are, sugges of so much historical and artistic association! When the re transfer (1866) of Venetia from Austria to Italy has prod its full results, railway extension will doubtless be fo among them. The islands westward of Italy, such as Cor Sardinia, and Sicily, have hardly yet entered upon the rai system.

Spain.—In the Spanish peninsula there were in 1851 o two railways, one of 18 miles from Barcelona to Mat another, 45 miles, from Madrid to Aranjuez. The latter 'inaugurated' with the ceremony of 'blessing the engines the cardinal archbishop of Toledo, in presence of the court, Cortes, distinguished attendants on royalty, troops and ha diers, and three miles of spectators. There are four classe carriages, the cheapest being without seats, and in which pas gers are allowed to carry a burden on their head without additi charge. Of 1340 miles of railway planned and partly exec in 1856, only a very small portion was actually open for tra Considering the hilly nature of much of the country, and backward state of commercial enterprise, Spain deserves s credit for her railways as they exist in 1866. There are l open extending from Madrid to Saragossa; from Saragoss Barcelona; from Saragossa to Bilbao; from the French fro near Biarritz, to Palencia; from Madrid through Valladoli Santander; from Palencia to Leon; from Olmedo to Zam from Madrid to Alicante; from Castillon to Albacete; f Cadiz to Seville and Cordova, and several smaller port Other railways are in course of construction, to touch

French and Portuguese frontiers at additional points. Two trains a day suffice for the traffic on most of the lines.

Portugal.—The western and smaller of the two states of the peninsula has only a limited amount of railway. There are lines from Lisbon through Coimbra to Oporto, from Lisbon through Evora to Beja, from Lisbon to the Spanish frontier near Badajoz, and two or three of slighter importance; and the year 1866 has been marked by the completion of a continuous railway between the Spanish and Portuguese capitals, Madrid and Lisbon.

Greece.—The once classical Greece has been too much distracted with the pulling down and setting up of kings, with the searching for brigands among the mountains, and with unsuccessful attempts to restore her damaged financial credit, to be able to achieve anything in railway enterprise.

Turkey.—The Danube and Black Sea Railway, about 40 miles long, extends from Kustendje to Tchernavoda, in Bulgaria; it cuts off an immense detour near the mouth of the Danube, thereby shortening considerably the time of travel from Vienna and Pesth to Constantinople. The Danube steamers touch in connection with the trains at Tchernavoda, and the Odessa steamers at Kustendje. This railway is in European Turkey. Another, the Ottoman Railway, is in Asiatic Turkey; it extends from Smyrna to Kos Bonnar, a distance of about 40 miles.

Africa.—The vast continent of Africa presents only three bits of railway. The first of these is the Egyptian Railway, from Alexandria to Cairo—130 miles—and then onward to Suez—90 miles. We shall have occasion to speak of this railway again in connection with the 'Overland Route.' The second is the Algerine Railway, a small affair, which the French have established in their African colony; it extends from Algiers to Bildah, through Boufarik. The third is a small length of railway near Cape Town, in the Cape of Good Hope.

East Indies.—India is benefiting in a most important degree by the construction of railways. Not only are productive labours encouraged, commercial transactions facilitated, the

movement of armies cheapened, and postal communication quickened; but the peculiar habits of the Hindus and Mussulmans are gradually undergoing changes which will remove some of the barriers between the natives and Europeans. The late East India Company began a system of guaranteeing 5 per cent interest or dividend on all the capital spent on the railways, with certain clearly defined obligations and conditions. The system having been found to work well, the imperial government of India are continuing it. The vast country is becoming penetrated in every direction. The East Indian, the Bombay and Central India, the Calcutta and South-Eastern, the Eastern Bengal, the Great Indian Peninsular, the Great Southern of India, the Madras, the Punjaub, the Scinde—all these are distinct railway companies, in some instances controlling vast lengths of line. When the several systems are completed, nearly all the great cities of India will be connected by rail—Madras, Seringapatam, Calcutta, Patna, Benares, Allahabad, Nagpoor, Hyderabad, Agra, Delhi, Lahore, Mooltan, Kurrachee, Bombay, &c.—from the mouths of the Ganges to those of the Indus. From Calcutta to Delhi alone there is an unbroken line more than a thousand miles in length. One railway company, the Bombay and Central India, have introduced a novelty in passenger carriages to which we have no parallel; viz., a carriage *two stories high*, like a two-storied cottage. They are constructed to hold a hundred and twenty passengers each, seventy on the lower story and fifty on the upper. By the mode of construction adopted, the weight and cost of the double carriage are less than of the ordinary carriage, although more capacious in the ratio of twelve to seven. By a little lessening of height in each story, the new carriages are only twenty-one inches higher than the old single-storied kind. They are only third-class carriages which are thus treated; but as third-class passengers form nineteen-twentieths of all the passengers on the line, it is fortunate that a change which is economical to the company is decidedly relished by the natives, who greatly favour the upper story of these carriages.

Australia.—'Young Australia' has begun to link her principal towns by rail. In Victoria, New South Wales, and Queensland, the three capitals—Melbourne, Sydney, and Brisbane—send out lines to some of the other towns; and others are in course of construction. None of the lines, however, as yet penetrate far from the coast; partly on account of the expense of construction, which is large. They are mostly government lines.

United States.—Crossing the Atlantic, we find a wonderful scene of railway activity. The outburst of railway enterprise in England excited a similar spirit in America. A short line of four miles from the stone quarries at Quincy to Boston had been constructed in 1827, and in 1829 several miles of the Baltimore and Ohio Railway were completed. Locomotive power was first introduced at Lackawannack, in 1828, on the line which connected the Delaware and Hudson canals. In 1830, Mr Redfield proposed the construction of a 'great western railway,' from the Hudson to the Mississippi river, a distance of 1000 miles. This was a magnificent project for that day, and has since been realised, by a series of lines stretching across the whole region. The Albany and Schenectady line, sixteen miles in length, was the first made in the state of New York; it was opened in 1833 with locomotive power. There were 1500 miles of railway in that state alone in 1851, and 9000 miles in the United States altogether, which had cost £60,000,000. The length in 1853 was no less than 14,500 miles.

A railway convention, attended by 465 delegates, was held at St Louis in 1849, to discuss the preliminaries of a great trunk-line from the Mississippi to California. This project was afterwards put forward in another form by Mr Whitney: he undertook, if Congress would grant a sufficient breadth of land, to lay down the line, with funds raised by the sale of the land on either side. This was a grand scheme; and it is hardly to be expected that American enterprise will stop short of locomotives across the Rocky Mountains. Meantime the Mormons commenced a wooden railway, to cross their territory from the Salt Lake to the hill country and to the sea-coast.

In 1855 it was computed that 17,500 miles of railway were open for traffic in the United States. In 1866 the network is nothing less than wonderful in extent. From Mitford in the state of Maine, where the United States system begins, there is a chain of unbroken links all down the Atlantic sea-board to Florida. Then along the northern boundary of the States, the railways border the St Lawrence and the great lakes very closely, in the states of New York, Pennsylvania, Ohio, Michigan, Indiana, and Wisconsin, to the mighty Mississippi. Then, along the course of the Missouri and Mississippi, and in the several states and territories of Minnesota, Iowa, Missouri, Illinois, Arkansas, Mississippi, Texas, and Louisiana, the locomotive whistles where the fur-hunter reigned supreme a few years ago. At the beginning of 1866 there were no less than 4700 railway stations in the United States and Canada. The nearest approach yet made to the mighty Rocky Mountains is by the St Louis and Kansas line, opened in September 1865—the first section of what is called the Great Pacific Railway, destined one day, no doubt, to cross the Rocky Mountains and reach California.

British America.—British America has not advanced so rapidly in these matters as could be wished. There have been conflicting interests in the various colonies of Canada, New Brunswick, Nova Scotia, and Newfoundland; there has been a disinclination on the part of the Hudson's Bay Company to encourage railways in the immense territory; and there has been in general less commercial activity than in the republic immediately adjoining. Still Quebec and Montreal are connected with the great Canadian lakes, and with the United States by rail; and some of the other colonies have effected a little. The chief company, the 'Grand Trunk of Canada,' has financially been very unfortunate. It must be credited, however, with the construction of the most stupendous railway bridge in the world—the *Victoria* bridge, over the St Lawrence at Montreal. Of this splendid work we shall speak in another section.

South America.—There is a short railway across the Isthmus of Panama, from the Atlantic to the Pacific, perhaps the most

profitable railway in the world. In the West Indies there are a few short lines, in Cuba, Jamaica, Demerara, &c. Brazil has entered to some extent on the construction of railways, and so have Chili and Peru; but the whole of South America has not done so much as some of the smallest European states.

§ VIII. GRAND ALPINE RAILWAYS: MONT CENIS.

THE greatest railway works on which engineers were engaged twenty years ago were those of the Britannia Bridge. The greatest in the present day are on the mountain border-land between France and Italy. What with the unprecedented tunnel through the mountains, and the rails about to climb over their summit, we may well consider the *Mont Cenis Railway* as one of the wonders of the world. This work, effecting a passage across the Alps, will connect the railways of France with those of Italy. There will be a tunnel of unprecedented length, beginning at Fourneaux and ending at Bardonnêche.

The idea of a tunnel through the Alps had long occupied the minds of engineers and statesmen both in France and Italy; but it is to the latter country that we must give the credit of having worked the idea into a practical shape. To pierce a tunnel seven miles long, by ordinary means, through hard rock, in a position where vertical shafts were out of the question, would be difficult, if not impossible. It was evident that if the project of a tunnel through the Alps was ever to be realised, some new system of mining must be adopted, by means of which a rapid and perfect method of ventilation could be insured, and which would greatly exceed the amount of work usually performed in any given time by the system hitherto adopted in tunnelling through hard rock. Accordingly, early in 1857, at St Pier d'Arena, near Genoa, experiments were undertaken before a government commission, to examine a project for a perforating

engine, proposed by Messrs Grandis, Grattoni, and Sommeiller, for rapid tunnelling. This machine was to be worked by means of air, highly compressed; which compressed air, after performing its work, would be an available source of ventilation. These experiments placed so beyond doubt the practicability of the system, that the law permitting the construction of the tunnel was speedily promulgated. Fourneaux was but a collection of mountain-huts, containing about four hundred inhabitants without means of supporting the wants of any increase of population. Nor was the case very different at Bardonnêche, a small Alpine village, situated at more than 4225 feet above the level of the sea, and populated by about one thousand inhabitants. The task of bringing together large numbers of workmen and their competent directing staff, must therefore necessarily be a difficult one. The machinery had to be transported through a country abounding in difficulties; and unexpected failures in some parts of it often threatened to prove insurmountable.

The first important work undertaken was the setting out of the centre line of the proposed tunnel. It was necessary first to fix on the summit of the mountain a number of points, in a direct line, which should denote the route to be taken; secondly, to determine the exact distance between these two ends; and thirdly, to know the precise difference of level between the same points. The line thus approximately determined, it was necessary to fix three principal observatories—one on the highest point of the mountain, perpendicularly over the axis of the tunnel; and the other two in a line with each entrance, in such a manner that, from the centre observatory, both the others could be observed. At the southern end the observatory could be established at a point not very far from the mouth of the tunnel; but towards the north the observatory had to be carried to a considerable distance beyond the entrance of the gallery. These three points remain as a check for those intervening, and serve as the base of the operations for testing the accuracy of the line of excavation. Contemporaneously was undertaken a careful levelling between the two ends, and bench-marks were

established at intervals along the whole line. All the data necessary for an exact profile of the work were now obtained. The exact length of the future tunnel was found to be about seven and a half English miles; and the difference of level between the two mouths 780 feet, the southern or Bardonnêche end being the highest. Instead of making a single gradient from Bardonnêche down to Fourneaux of about one in fifty, two gradients were made, each inclining towards the respective mouths.

In the interval between the end of 1857 and that of 1858, many important works had been pushed forward. At Bardonnêche, bridges and roads had been constructed for facilitating the transport of the heavy machinery. Houses for the accommodation of the workmen had been rapidly springing up, together with vast edifices for the various magazines and offices. The canal, more than 1½ mile in length, for conveying water to the air-compressing machines, was constructed, and the little Alpine village had become the centre of life and activity. At Fourneaux, works of a similar character had been put in motion. In June 1859, the erection of the compressing machinery was commenced at Bardonnêche; but it was not before November 1860 that five compressors were successfully and satisfactorily at work. In January 1861, the boring-engine was introduced for the first time into the tunnel. Very little useful result was, however, obtained for a long and anxious period, beyond continually exposing defects in the perforators. Actual practice forced into daylight numberless little defects which theory only too easily overlooks; but there was no lack of perseverance and ingenuity on the part of the directing engineers. In May 1861, it was considered necessary to construct a large reservoir on the flank of the mountain, to act as a deposit for the impurities contained in the water, which often caused serious inconvenience in the compressors. In the whole of the first year, 1861, the advance made was but eighteen inches per day of twenty-four hours, an amount less than might have been done by manual labour in the same time. In 1862, however, the advance made

was raised to three feet nine inches per day. In 1863, the length done (always referring to the south or Bardonnêche end) was raised to above 1300 feet. At the Fourneaux or northern end—owing to increased difficulties peculiar to the locality—the perforation of the gallery was much delayed. A totally different system of mechanism for the compression of air was necessitated; and it was not before January 1863 that the boring-machine was in successful operation on this side. In September 1864 were completed in all rather over 3960 feet of tunnel. Basing our calculation on this rate alone, we may look forward to the opening of the Mont Cenis Tunnel at about the year 1875. The directing engineers are, however, of opinion that this period may be considerably reduced, unless some unlooked-for obstacles are met with.

In using the machines, a perfect ventilation of the tunnel has been secured by the compressed air escaping from the exhaust of the boring-engines; or by jets of air expressly impinged into the lower end of the gallery to clear out rapidly the smoke and vapour formed by the explosion of the mine.

Besides the great tunnel itself, the works beyond its southern or Italian end are exceedingly formidable, and will tax the skill of the engineer as much as any road yet attempted. Its total length, from Susa to the mouth of the Mont Cenis Tunnel, will be about 24 miles; and the difference of level between these two points is about 2500 feet. There will be three tunnels of importance, three others of lesser dimensions, and twelve other small tunnels. The total length of tunnel on these 24 miles of railway will be nearly 21,000 feet, or about 4 miles—just one-sixth of the whole line. There will also be several examples of bridges and retaining walls of unusual dimensions.

The works being carried on at Bardonnêche are on a larger scale than at Modane. There are, near this Bardonnêche end, two houses in a direct line one with the other—one situated at the foot of a steep ascent, and the other at about 70 or 80 feet above it, on the side of the mountain. These two houses are, however, but *one*, being joined by ten rows of inclined archwork

Along the summit of each row of arches is a large iron pipe, more than a foot in diameter. These ten pipes, inclined at an angle of about forty-five degrees, come out of the side of the upper house, enter the side of the lower house, and serve to conduct the water from the reservoir above to the air-compressing machinery, which is arranged in the house below, exerting on this machinery the pressure of a column of water 84 feet 6 inches in height. In the compression-room are ten compressing-machines, and two machines like a couple of small steam-engines, only they are worked by compressed air instead of steam. Each of these imparts a rotary motion to a horizontal axis extending along the whole length of the room, on which are a series of cams, which regulate the movements of the valves of the great compressors. The whole arrangement is very elaborate. A descending column of water compresses air to a power of six atmospheres; this compressed air sets in action the air required; the rotating shafts act on the valves of the great compressors; and the compressors work the boring-machines. If these machines in the tunnel cease working, the pressure augments in the recipients, and the water in them falls until an equilibrium is established. On the other hand, if additional air be used for ventilating the tunnel, or by an accidental leakage in the conducting pipes, the water rises rapidly in the recipients, and consequently in the water-gauge outside. By this means a continual compensation of pressure is kept up, which causes the machine to work with the regularity of a steam-engine provided with a governor. Much doubt had previously been expressed as to the possibility of conveying compressed air to great distances without serious loss of power. The experience gained, however, at Mont Cenis has shewn that, conveyed to a distance of 13 English miles, the loss would be but one-tenth of the original force.

The mouth of the tunnel is but a few hundred yards from the air-compressing house. In the completed portion of tunnel there is nothing very different from an ordinary railway-tunnel, with the exception of the great iron pipe which conveys the

compressed air, and is attached to the side of the wall. In those portions where the workmen are engaged in the somewhat dangerous operation of detaching large blocks of stone from the roof, the pipe is protected by a ceiling of massive beams. A tramway is laid along the tunnel; beneath the tramway is a canal for carrying off the water; and in this canal are placed the pipes for conveying the compressed air to the machines, and the gas for illuminating the gallery. There are ten perforators independent of one another, all mounted on one frame, and each capable of movement in any direction. Attached to each are two flexible tubes, one for conveying the compressed air, and the other the water which is injected at every blow of the tool into the hole, for the purpose of clearing out the débris, and cooling the point of the 'jumper.' In front, directed against the rock are ten tubes, similar in appearance to large gun-barrels, out of which are discharged with great rapidity an equal number of boring-bars or jumpers. Motion is given to these jumpers by the admission of a blast of compressed air behind them, the return stroke being effected by a somewhat slighter pressure of air than was used to drive them forward. On an average, at the end of about three-quarters of an hour, the ten holes are pierced to a depth of 2 feet to 2 feet 6 inches. Another ten holes are then commenced, and so on, until about eighty holes are pierced. Precautions being then taken, the miners advance and charge the holes in the centre with powder, and adjust the matches; the fuse is fired, and the miners retire behind the folding-doors which are closed. The explosion opens a breach in the centre part of the front of attack. Powerful jets of compressed air are now injected, to clear off the smoke formed by the powder. Then the other holes in the perimeter are charged and fired, and more air is injected. Gangs of workmen next clear away the débris and blocks of stone detached by the explosion, in little wagons running on a pair of rails placed by the side of the main tramway. Whatever may be the nature of the rock, if it is very hard, the depth of the holes is reduced. Each jumper gives about three blows per second, and makes one-eighteenth

of a revolution on its axis at each blow. It is found that, on an average, one perforating machine is worn out for every six mètres of gallery; so that more than 2000 will be consumed before the completion of the tunnel. The north or Modane end of the tunnel is differently managed. Six large water-wheels moved by the current of the river Arc give a reciprocating motion to a piston contained in a large horizontal cylinder of cast iron. This piston, having a column of water on each side of it, raises and lowers alternately these two columns, in two vertical tubes about 10 feet high: compressing the air in each tube alternately, and forcing a certain quantity, at each upward stroke of the water, to enter into a cylindrical recipient. There is but little loss of water in this machine, which in its action is very like a large double-barrelled common air-pump. The system employed at Modane has many advantages; and its success has given a marked impulse to the modern science of tunnelling.

It may be well to remark that *Mont Cenis* is not a suitable name for the tunnel. That Alpine height is sixteen miles away from any part of it. The actual peaks under which the tunnel passes are the *Col Frejus*, the *Grand Vallon*, and the *Col de la Rue;* the Grand Vallon, the highest and middle peak of the three, is 5400 feet above the level of the tunnel, and 11,000 above the sea-level. The tunnel itself is thus at a greater height above the sea than any mountain-top in Great Britain. It will also be well clearly to remember that the necessarily slow progress of the tunnel is owing to the impossibility of working it at more than two points at once, beginning at the two mouths and working towards the centre; the mountains above the tunnel are far too high to permit shafts to be dug down through them. Mr Buffum, who visited the works in October 1865, states that, three or four months before that date, the perforators had begun to encounter white quartz, a rock harder than had been hitherto found; as a consequence, the labour was greater, and the rate of progress lessened. In January 1866, the perforators on the French side had gone 2459 yards into the bowels of the mountain, and on the Italian side 3358 yards—about three and one-third

miles out of seven and two-thirds. When finished, there will be nearly eight miles of tunnel from Fourneaux to Bardonnêche, and thirty-four miles of difficult railway works to connect the tunnel with the French railways at St Michel at the one end and the Italian railways at Susa at the other. These forty-two miles altogether will cost not less than £3,500,000.

There is still another enterprise to be noticed, in connection with this grand Alpine railway. Italy and France will have to wait several years before the Mont Cenis tunnel can be finished; the more hopeful prophets name the year 1870, while the less hopeful extend the probable time to 1875. Under these circumstances, a bold determination has been made to carry a railway *over Mont Cenis itself*, keeping the present traveller's route—Napoleon's fine road. No locomotive has yet climbed such an ascent as this road presents, if used in the ordinary way. It has therefore been determined to use a third rail, against the sides of which horizontal wheels will press, to be worked by the engine in addition to the ordinary driving-wheels: the horizontal wheels, by *biting* the centre rail, will prevent the engine from slipping backwards, and will also assist it round the curves, which are sharper than have ever been worked. The weight of the engine itself may be safely reduced under these circumstances. Trials, made in Derbyshire, on the High Peak Railway, and on a small bit of experimental railway at Mont Cenis, have satisfied engineers that an ascent so steep as 1 in 12 can be surmounted by these means. This experimental portion is a mile and a quarter long, near Lanslebourg, on the Savoy side of the Mont. As the existing road is a succession of zigzags, with sharp turnings at the corners, the rails have been laid in the same way, with curves of two chains radius. The road itself is somewhat over thirty feet wide, and the railway is to occupy the inner portion. Up the steep bit of experimental incline trains have been propelled twelve miles an hour. Italian, French, English, Austrian, and Russian engineers examined into the subject in 1865, and came to a unanimous conclusion that the object can be attained, with immense advantage to passenger and goods traffic. A very

influential company has been formed for carrying out the plan, with necessary privileges conceded by the Italian and French governments. The engineers estimate that £8000 per mile will suffice to lay down a single line (with three metals) of rail, including locomotives. The railway will be protected in certain places from accumulations of snow by covering it with a roof of timber and iron. A snow-plough, attached to the engine, will suffice to clear away the occasional drift. It is supposed that the work will be finished in 1867; and so confident are the company of the resources of the line, that they expect it will pay itself in seven years. Savoy and Piedmont will eventually, if all goes well, possess two railways for crossing the Alps, one through the great tunnel and one over the pass. Pleasure-travellers are likely to prefer the latter, as affording a better view of the country. These once finished (or either of them), there will be unbroken railway communication from Calais and Boulogne to the southern extremity of Italy.

§ IX. OTHER FAMOUS RAILWAY CONSTRUCTIONS.

In illustrating the engineering wonders of the railway system, it will be more useful to notice what is doing abroad than at home, as being less familiarly known; although the latter should of course be kept in view, as types by which others may be judged. The *Menai Bridge*, already described, will have given a good notion of the tubular principle of construction. The high-level bridge at Newcastle-on-Tyne supplies a fine example of a mode of making a double bridge, having a railway over a roadway. The long bridge over the Tweed at Berwick has encouraged engineers to grapple with formidable difficulties at Runcorn over the Mersey, at Saltash over the Tamar, and elsewhere. There are daring plans in progress for crossing the Humber at Hull, and the Severn at New Passage. There are viaducts of great

height and beauty, such as the Crumlin Viaduct; and tunnels of considerable length, such as those at Box and Woodhead. Let us say simply a few words touching the Tamar Bridge and the Cannon Street Station, before going to other countries.

The *Albert Railway Bridge* at Saltash is worthy of the original mind which devised it. The river Tamar is half a mile in width at Saltash; and the manner in which Brunel spanned this half mile with a lofty bridge is very remarkable. Two gigantic spans of 455 feet each rest mainly on a pier built in the middle of the stream; and nineteen land arches connect these spans with the Devon and Cornwall railways. To build the central pier Brunel employed a novel form of coffer-dam. He constructed an immense wrought-iron cylinder, 37 feet in diameter and 1[illegible] feet high, and sank this to the bottom of the water. The water was pumped out, the air forced in, and men worked at the bottom of the cylinder, clearing away the mud and gravel. When the rock was fairly laid bare, a granite pier was built upon it, and carried up to a height above the level of the water. On this granite pier were erected four iron columns of colossal proportions, being no less than 10 feet in diameter by 100 feet high; and a massive lattice-work of wrought-iron connects them to prevent lateral movement. The two side piers, at the Devon and Cornwall shores, are of solid masonry, 29 feet wide, 17 feet thick, and 190 feet high from the foundation. For the roadway over the two great spans, Brunel adopted the suspension principle, though not in the usual form. He constructed two enormous metal bows or arches, high up above the roadway, and suspended the road from them. Each of these monstrous wrought-iron tubular bows consists of an elliptical tube, 12 feet high by 17 wide; it is made of inch boiler-plate, and strengthened within in various ways. The tubes were lifted by the aid of hydraulic rams of enormous power, temporarily erected on the piers themselves. Thus the piers and the tubes rose together, to a total height of no less than 260 feet from the foundation of the centre pier to the highest convexity of each bow. The roadway is mainly suspended from the bows;

chains, each link consisting of fourteen bars of iron, six inches wide by one inch thick. The tubes, and chains, and roadway are all so connected by rods and trusses that the piers have to bear each its own portion of weight pressing fairly downwards, but no side pull or straining. Engineers themselves say that in difficulties of construction Brunel's Albert Bridge excels Stephenson's Britannia Bridge. It is a pity that Mr Brunel's magnificent creations should so often have been unprofitable to those who had to pay for them. His mind could not willingly descend to that balance between cost and means which is so essential to commercial success. While Brunel was executing works which redound to his own fame, but which shareholders deplore, Mr Locke was constructing railways through hilly districts so economically as to come at once within the legitimate resources of the companies.

The *Cannon Street Station* of the South-Eastern Railway is a wonderful example of what our railway companies will undertake; seeing that it is, after all, only one London terminus for one company. The station, in its depth of 700 feet from Cannon Street to the Thames, and its width of 200 feet from Dowgate Hill to Bush Lane, has absorbed no less than 27,000,000 bricks. There is cellarage amounting to 140,000 square feet. The iron employed is more than 2000 tons. One magnificent roof covers the whole, in a single arch rising to a height of 106 feet. The river façade has bold ornamental towers at the corners; these will be used as capacious water-tanks. The station has nine lines of rails and five platforms; besides a cab and carriage road entering at Thames Street and emerging at Cannon Street. These figures are irrespective of the magnificent hotel, which, although it forms the Cannon Street façade of the station, is a separate undertaking.

France is not without its grand railway structures; but we shall find something more distinctive on the Rhine, at Cologne and at Mayence. The great *Cologne Railway Bridge* is remarkable for the way in which road and rail traffic are provided for simultaneously. Down to 1854, an old bridge of boats was left

in undisputed possession of the passage. In that year a plan for a new bridge was drawn up by the engineer Lohse, in which the middle portion should be a carriage road, with lateral lines on one side for a railway, and on the other for foot-passengers. The bridge was commenced in 1855; but a change of plan was made, by which the railway line would be placed on the other side. Without disturbing the piers, it was thereupon determined to build two separate iron bridges in juxtaposition; one of [illegible] feet wide, for two lines of rail; and one about the same width for road vehicles and foot-passengers, having a carriage-way and two foot-pavements. Then, in 1858, when the Rhine captains complained that there was not height enough for their masts beneath the bridge, the whole height was raised, thereby greatly affecting the plans generally. At last the bridge was finished in 1859. It is 1352 feet long, with four spans for river traffic underneath. The cost was about £600,000, a very large sum for a German work of this kind. The other grand Rhenish bridge, at *Mayence*, was opened in 1862. It is constructed on the 'fish-shaped girder' system. It consists of thirty-two openings or spans, the total length of which is 3400 feet, nearly four times that of Westminster Bridge. The lattice-girders, looked at sideways, are nearly fish shape, bending upwards at the top and downwards at the bottom. M. Pauli, the engineer, had calculated certain formulæ of tension and resistance which result from such a formation; and he had already tried the system successfully in a bridge near Munich. The bridge crosses the Rhine very obliquely, and the centre openings have the formidable span of 332 feet each.

The *Sömmering Railway*, crossing the Noric Alps from Vienna to Trieste, is the grandest public work in that part of Europe, and one to which we have no parallel in England for engineering difficulties. How the railway crosses ravines, winds round precipices, and bores through mountains, is astonishing. The most difficult portion is that from Glognitz to Mürzzuschlag, comprising the crossing of the Sömmering Pass at a height of 3425 feet above the sea-level. There are no less than fifteen

tunnels and sixteen viaducts in this section of 26 miles. The tunnel which pierces the Sömmering is 2000 feet higher than the station at Glognitz. The curvatures are incessant, and some of them very sharp. The trains constantly run close to the brink of fearful precipices, which are guarded by strong balustrade walls. No locomotives being then powerful enough to climb such severe and continuous inclines, prizes were offered for new constructions; and these resulted in the production of locomotives which master all the difficulties of the Sömmering. The line was opened in 1854. It is said that a much better route from Vienna to Trieste could have been found, traversing a portion of Hungary; but that the Austrian government, jealous of the Hungarians, preferred that the line should not in any part touch the Magyar provinces.

Spain has the credit of constructing the remarkable *Ebro Railway Bridge*, near Viedola. The bridge consists of twenty-one spans of lattice-girders, each about 100 feet in diameter. The piers are formed of iron cylinders, varying from six to eight feet in diameter, sunk through the bed of the river to an average depth of 30 feet, and resting on the solid rock beneath the river bed. As there is no suspension principle adopted, the roadway is mainly formed by the lattice-girder, made of such strength as to cross the spans with strength and steadiness.

Across the Atlantic, in the midst of a system of bridges and viaducts worthy of the energies of the new world, there is one of surpassing merit and grandeur, for which our own colony of Canada must be credited. This is the mighty *Victoria Tubular Bridge* at Montreal, crossing the broad and rapid river St Lawrence, and unquestionably taking the lead among all railway bridges hitherto constructed. This bridge forms a necessary part of the main line of railway communication by which the produce of the interior is brought to the ports of the Atlantic. The *need* was readily to be seen; but the St Lawrence is a rapid stream, above a mile in width, whose channel becomes so choked with ice in winter, as to seem to make engineering works impossible. Nevertheless, the idea was formed by a citizen of

Montreal in 1846; and in December 1859 the first train passed over the actual structure. The fabric consists of twenty-four piers, rising 60 feet above the water, with intervals of 242 feet in all instances but one in the centre, which is 330 feet; the upper end of each pier being in a sloping form, to meet the dangerous masses of ice which pour down the stream in winter. Along the tops of the piers is laid a quadrangular tube of plate-iron, 16 feet in breadth, 18 feet 6 inches high at the extremities, and 22 feet in the centre in height; this tube, of course, containing the carriage-track. Such—with abutments at the extremities—are the simple elements of the structure; but the internal strengtheners are both vast and numerous.

The tubular principle having been resolved upon, after the model of the Menai Bridge, it seemed only right and fitting that the aid of Mr Robert Stephenson should be called in by the projectors. He visited Canada for this purpose in 1853. It is admitted, however, on all hands, that the hardest part of the engineering was borne by Mr Ross. On the plan being perfected, a prodigious system of labour was organised by Mr James Hodges, as representing the contractors. It comprised 450 quarrymen, shipping to the extent of 12,000 tons, manned by 500 sailors, and 2090 workmen of other descriptions, exclusive of those required for the preparation of the tube, which was executed piecemeal in England. The work was commenced in January 1854, when the surface of the river was composed of a deep *pack* of ice fragments, thickly coated over by a newly frozen sheet. On this firm surface, a peculiar piece of wooden framework, called a *crib*, was formed, such being a necessary preparative to the forming of a coffer-dam in which to lay the foundations of the first pier. In the course of the summer and autumn, two coffer-dams were formed, and in one of them a pier had been built; but the dams gave way on the 4th of January 1855, when the pack of ice broke up. The accumulation had been going on for four days, until the river had risen high above its usual level, and lay in a widely extended sheet over the adjacent country. 'At length,' to pursue a narration which we owe to Mr Hodges,

'some slight symptoms of motion were visible. The universal stillness which prevailed was interrupted by an occasional creaking, and every one breathlessly awaited the result, straining every nerve to ascertain if the movement was general. The uncertainty lasted but a short period; for in a few minutes the uproar arising from the rushing waters, the cracking, grinding, and shoving of the fields of ice, burst on our ears. The sight of twenty square miles (over 120,000,000 tons) of packed ice (which but a few minutes before seemed as a lake of solid rock), all in motion, presented a scene grand beyond description. The traveller-frames, and No. 2 dam, glided for a distance of some hundred yards without having a joint of their framework broken. But as the movement of the ice became more rapid, and the fearful noises increased, these tall frameworks appeared to become animate; and after performing some three or four evolutions like huge giants in a waltz, they were swallowed up, and reduced to a shapeless mass of crushed fragments. After gazing at this marvellous scene in silence, till it was evident that the heaviest of the shoving was over, all those in the transit tower, from which it had been witnessed, began to inquire how the solitary pier No. 1, which had been battling alone amid this chaos, had escaped. Although some affected to entertain no fear, the author confesses, for his own part, to have felt infinitely relieved when, upon looking through the transit instrument, he discovered that the pier had not been disturbed.'

It was against difficulties and dangers like these, and in the narrow intervals of time when the nature of the climate permitted men to work, that the masonry of the Victoria Bridge proceeded. Meanwhile, the preparation of the plates required for the tubes proceeded at the Canada Works in Birkenhead. A plan or map of each tube was made, upon which was shewn each plate, T-bar, angle-iron, keelson, and cover-plate required in the different situations, with the position of each marked by a distinctive character or figure. As the work advanced, 'every piece of iron, as it was punched and finished for shipment, was stamped with the identical mark corresponding with that on the

plan; so that when being erected in Canada, although each tube was composed of 4926 pieces, or 9852 for a pair, the workmen, being provided with a plan of the work, were enabled to lay down piece by piece with unerring certainty till the tube was complete.' Meanwhile, the masonry of the piers was accelerated in its progress by many ingenious contrivances, due to Mr. Chaffey. A stock of 10,000 tons of stone was placed in such position in the stone-yard, prior to the commencement of the masonry, as to admit of each distinct course being kept separate and readily accessible when required. To effect this, a *steam traveller*, 66 feet in length, placed on a ghanty-frame raised [illegible] feet from the ground, and extending about 600 feet in length, was constructed. The boiler and engine were attached to the *jennie*, and traversed laterally along the traveller, being provided at the same time with a gearing to admit of a motion being communicated to the traveller, driving it from one end of the staging to the other. With this machinery, worked by one boy, a train of cars, loaded with the heaviest blocks of stone, could be moved on the railway-track, underneath, backwards and forwards, as required, and the stones taken up and deposited together, according to the courses they were intended for.

The work was completed at the close of 1859, and tested in a severe manner by the passing of a train of platform cars, [illegible] feet in length, loaded with stone to the utmost; when even the central and longest tube was found to be deflected to an extent of less than two inches. It needed but this fact to perfect the glory of a work which promises to be an enduring monument of British skill, enterprise, and perseverance.

A writer in *Chambers's Journal*, describing a visit to the bridge in 1860, said, in reference to an inspection of the tube, 'We walked in to about the centre, where an opening and a ladder enabled us to get upon the top, so as to survey freely the marvellous fabric, and its surroundings. Everything seemed severely simple, yet perfectly adapted to its purpose. A side opening, in like manner, enabled us to observe the form and structure of the piers. Then the word was given that a train

was approaching from the south end, and it was necessary to stand aside, and allow it to pass. Our party followed the example set by a few workmen near us, and ranged themselves close to the plates forming the side of the tube, between which and the rail-track only a space of about two feet intervenes. On came the huge noisy object, looking as if it would sweep us all into destruction—it was impossible, with the utmost faith in what we were told of safety, to repress some little tremors. Certainly any sudden faintness at such a moment might have been attended with fatal results, for nothing but an erect position could save us. The blinding and deafening mass passed in its undefined lineaments close to our faces, and I experienced, though I did not express, a feeling of relief when we again saw the empty tube before us, and observed the train wheeling quietly out into the light at the north end. As to the imperfect light within, this is obtained through round holes pierced at intervals in the side plates, at the places where their weakening effect is least felt.'

The *Niagara Railway Bridge* must certainly take rank among the important engineering works of the age, defying, as it does, the wonderful cataract which has acquired such world-wide notoriety. The New York Central Railway Company and the Great Western of Canada Company divided the cost between them, seeing that both would benefit by its formation. The principle of construction is one that has not been much adopted in England. Instead of flat wrought-iron thick plates, connected by pins passing through their extremities, the suspension is effected by a wire-cable, or rather four wire-cables, of the enormous bulk of ten inches diameter. Each cable is composed of nearly 4000 wires. They are securely anchored in the solid rock, 30 feet below the surface, and pass over the tops of four stone towers 80 feet high. The roadway hangs from the cables by 624 suspending-rods. There are also about 100 iron stay-rods, of formidable strength. The span between the towers is 800 feet, and the height of the rails above the water is no less than 250 feet. Probably, no suspension-bridge in the world

would allow trains to pass over it at ordinary speed, without endangering either the bridge or the trains: so great would be the up-and-down deflection and the side-to-side swaying. At Niagara it is deemed satisfactory to obtain a speed of five miles an hour over the bridge, without any very considerable oscillation. The roadway on which the rails are laid is a remarkable structure. It is a kind of lattice or tubular girder, with a railway *outside* on the top, and an ordinary carriage and foot-passenger way *inside* on the bottom. This, and the graceful curvature of the cable-chains, combine to give lightness and elegance of appearance to the bridge; while the roaring rapid beneath, and the stupendous Falls not far distant, impart new elements of interest to the scene. Mr Roebling, the engineer, constructed the bridge at a cost of about £80,000. It was opened for traffic in 1855.

The *Santiago and Valparaiso Railway*, in Chili, is worthy of notice, on account of the formidable obstruction which the Andes present. It is very creditable to the Chilians that they should have finished such a grand work, and opened it for traffic in 1863. The railway is 114 miles long. It has five tunnels, several viaducts varying from 70 to 130 feet in length, and an incline of twelve miles rising 125 feet per mile. It crosses one of the passes between the lesser Andes, after rising 2640 feet from Valparaiso. For some miles the railway climbs along the face of precipitous cliffs, with abysses of many hundred feet below it, and walls of porphyry rock rising 1000 feet above it, seldom disturbed by other denizens than the eagle and the condor. Although this is the longest and most important railway in South America, it is not the most elevated; the Copiapo line crosses the Andes by a pass 4400 feet high.

The works on several of the Brazilian railways are in many instances very heavy; those on the Dom Pedro Segundo line, running inland from Rio de Janiero, being particularly so. But the most interesting work in South America is the incline on the San Paulo Railway, on the ascent of the Serra do Mar. This line commences at Santos, a port of rising importance, and extends inland about 80 miles to Jundiahi, the

centre of a highly productive district. For the first 14 miles, the country is merely a flat swamp, after which the ascent begins, and the line is conducted up the side of the mountain by a series of four inclines of less than 1 in 10 for six miles—the total ascent being in that distance 2572 feet. The inclines are worked by four stationary engines and wire ropes; and Mr Brunlees, the engineer, has adopted the system of having a centre rail for a *clip-break*, similar to that he recommended for the road railway over Mont Cenis, with great success; as, to quote his Report, 'in many trials made at speeds varying from 6 to 10 miles an hour, there was no difficulty in coming to a dead stop in a few yards.' The works on the inclines are perhaps the heaviest of the kind in the world, but the rest of the line is simple enough. Eighty tons of goods can be taken up these inclines, and the same quantity let down in an hour.

Among the many noble engineering works which the railways of India comprise, one is the *Jumna Bridge* at Delhi. It is a beautiful specimen of the lattice-girder construction, in twelve spans of 205 feet each. It consists of two principal girders, each having a double-top and double-bottom, the top and bottom being united by diagonal lattice bars, so as to form one main girder. The top or outside of the girder forms the railway, while the bottom or inside forms a roadway for ordinary vehicles. This is one of several bridges recently constructed, in various countries, which avoid the heavy appearance of the Menai Tubular Bridge by having the sides open lattice-work instead of continuous iron-plate. India has still more reason to be proud of the *Bhore Ghaut* works of the Great Indian Peninsular Railway. The distance from Bombay to Poonah, about 70 miles, is marked by the occurrence of the Bhore Ghaut, a pass in a mountain-range 2000 feet high. Sir John Malcolm constructed a carriage-road to the Ghaut thirty years ago; but his gradients were not admissible for a railway, and therefore new surveys had to be made.' First, starting from Bombay, the railway has to struggle against the numerous salt-water creeks which branch out of the harbour. It then threads its way through groups of

isolated hills, to Callian, and advances onward to the Deccan by the Bhore Ghaut. Below Campolee commence the great works in earnest. The ascent averages one in forty for the whole of the 14 miles. The tunnels are numerous; and one of the viaducts is 150 feet above the level of the ravine beneath. At one point the engineers could neither tunnel, scarp, nor construct viaducts to climb a particular elevation, and therefore they adopted the method of zigzag. In this method a railway-train does not turn any corners; it is dragged up an incline on the side of a hill or mountain; the engine is then shifted to the other end, where it drags in an opposite direction up another incline: and so on time after time; but in this case only one reversing station is necessary. As many as 10,000 native work-people were employed in these operations for several years, at wages which seemed to them noble, fourpence to sixpence per day. A handful of English overseers and foremen kept them all steadily at work. There was a terrible accident on this line in 1865, whereby an engine, driven too rapidly down one of the inclines of the zigzag, precipitated the train to a depth beneath.

§ X. ILLUSTRATIONS OF RAILWAY WORKING.

WE shall now touch lightly on a number of particulars which, taken collectively, will serve to illustrate many minor features of the railway system.

Underground Railways.—Among the best known railway tunnels are the Woodhouse (5192 yards), Box (3227), Littleborough (2869), Sapperton (2800), Kilsby (2423), Liverpool (three each about 2250 yards), Clayton (2200), Abbot's Cliff (2000), Watford (1793), Merstham (1780), Leicester (1760), and Clay Cross (1760). All these and several others are a mile or more in length each, one nearly three miles; while those below a mile might be reckoned by scores. An underground railway, however, as the term is now understood, means a railway carried immediately beneath a public carriage roadway, to lessen the

cost of construction. The chief of these is the *Metropolitan Railway*, extending about five miles from Paddington to Finsbury, three-fourths of it tunnel, and the rest open overhead. The tunnelled portion has openings at intervals for light and ventilation, and also for stations. The locomotives are constructed in a peculiar way, to condense the products of combustion. To prevent collisions in so dark a railway, with nine stations in a length of five miles, a scrupulous system of telegraphic signals has been organised, enabling each station-master to know exactly the positions of the nearest trains, both up and down. The carriages are of immense size, some of them with eight compartments for twelve or fourteen passengers each; and they are brilliantly lighted with gas. There are 200 trains a day in each direction, well filled with passengers (amounting to 16,000,000 in 1865); and although the average fare per passenger barely reaches 2½*d*., the receipts mount up to £800 per mile per week.

Pneumatic Railways.—The idea of propelling carriages by atmospheric pressure was first suggested by Vallance at Brighton in 1824. A tunnel was to be made, air-tight, and large enough to receive carriages, which, on the exhaustion of the tube by steam-power, and the admission of air at one end, were to move rapidly under the influence of the pressure. On this plan passengers would have had to travel in the dark. It was afterwards shewn that small continuous tubes, worked on the same principle, might be made available for the rapid transmission of letters. Next Medhurst, in 1827, and Pinkus, in 1834, proposed improvements. In 1839—40, Clegg and Samuda laid down a mile of atmospheric railway, as a working-model. A nine-inch iron tube was fixed between the rails, having on its upper side a continuous longitudinal valve. A piston was connected with the carriage by a bar passing through the valve; and this, on the admission of air after exhaustion, travelled forward with a load of nine tons at 30 miles an hour. The valve being made with an elastic hinge, opened readily as the bar advanced, and closed again immediately behind it, being kept air-tight by a composition

of oil and tallow. About the same time Roberts proposed to establish an atmospheric railway across Dartmoor—the tube to be exhausted by water-power. A line of two miles from Dalkey to Kingstown, in extension of the Dublin and Kingstown line, was constructed in 1843, passing through a district with sharp curves, and gradients in places of 1 in 50—circumstances to which the atmospheric system is especially applicable. Other attempts made to establish a similar system on the London and Croydon, and on the South Devon lines, failed entirely—chiefly from imperfection in the valve, and difficulty in stopping at the stations. A contrivance of racks and wheels in place of the continuous valve, was proposed by Pilbrow in 1844; and later a new form of valve by Hallette—two small inflated flexible tubes which, acting as closed lips, would allow of the passage of the piston, and, at the same time, exclude the air. The subject was revived in 1861, by the project for a *Pneumatic Dispatch*, a mode of transmitting mail-bags to the General Post-office, and parcels to the carriers' offices, from the principal railway termini. After a successful experiment in Battersea Fields, a pneumatic tube, between four and five feet in diameter was laid down beneath the public streets, from Euston Square to Holborn, eventually to be extended to the General Post-office. Matters are not yet sufficiently advanced in 1866 to report on the merits of the system. Meanwhile, and consequent on experiments made in 1864 in the grounds of the Crystal Palace, a pneumatic railway is being made under the Thames from Whitehall to Waterloo Station; it is to be large enough to contain a broad-gauge passenger-carriage running upon rails, to be propelled by compressed air in one direction, and drawn by a kind of suction by rarefied air in the other.

Submarine Railways.—A railway under the English Channel from Dover to Calais, 20 miles long, seems so chimerical that few persons treat the matter seriously. Yet it will not do to apply the term 'impossible' even to this scheme, seeing that many of the results now regularly produced by railways were at one time authoritatively pronounced impossible. Let it suffice

therefore, to mention at present (1866) that several different plans have been brought forward for this purpose.

Railway Aid to Intercourse.—Taking railways just as they are, without prophesying as to the future, what a wonderful aid to society they have become! Are the London markets over-supplied?—straightway the excess is forwarded by rail to Birmingham, Manchester, or other great centres of provincial population; and tons of vegetables, fruit, eggs, poultry, or fish, which in one place would have lacked a market, form an acceptable supply to hundreds of willing customers in another. The produce of remote agricultural districts has now a value altogether unanticipated a few years ago, and nature's redundant bounties are beneficially distributed. The mineral produce of Yorkshire and the midland counties is now poured into new and wider markets; and the inhabitant of London, as well as of other towns, hitherto supplied with fuel at a high cost, now saves one-third in the price of the coals he consumes. And to a still greater extent is social intercourse promoted. Hundreds of thousands who, thirty years since, had scarcely ventured beyond earshot of the bells of their native village, have now travelled to the county town—or to London, that cynosure of the rural eye; while the dwellers in the noisy city, in the busy marts of trade, have traversed the land hither and thither, viewing the wonders of art and of nature with eagerness, and have experienced the gladness of feeling, which fair landscapes and fresh breezes inspire. Without railways, the two Great Exhibitions of 1851 and 1862 would have been mere local shows: whereas, with their aid, millions of spectators, gathered from all lands, witnessed the marvellous displays, and returned to their homes scarcely less astonished at the rapid locomotion of their journey than at the results of collected industry. Without railways, too, postal reform would have been as a bird without wings. What printing did for the grand truths of the fifteenth century, has been done for social intercourse and commerce by railways in the nineteenth. Almost unlimited capabilities for the transmission of correspondence are now afforded to

the mail service. 347,000,000 letters were conveyed and delivered in 1850—an almost fivefold increase over 1839; and the number rose to 720,000,000 in 1865. With a celerity and regularity not less remarkable than beneficent, the orders of government, calls of trade, messages of love and friendship, tidings of joy and sorrow, of all the hopes and aims, doubts and fears, which actuate a family or community, are despatched to every county and to every town and village in the land. Perhaps there could not be more trustworthy evidence of the value of railways to postal communication, than is furnished in the Postmaster-General's Report prepared in 1865,* relating to the operations of 1864. We cannot afford space to transcribe it here, but may simply say that it shews how, by the opening of new railways, the course of post was accelerated one whole day between London and various provincial districts. Cornwall, North Wales, Ireland, and especially the northern parts of Scotland, from Perth to Sutherland and Caithness, have been greatly benefited by these rail-and-mail facilities.

Clearing-House System.—One of the capital features of the railway system is the plan of what is called the *Clearing-house.* To carry passengers without interruption to the furthest point of their journey, irrespective of the diversity in ownership of the lines over which they passed, was a necessity that increased with every increase of the railway system. To meet certain practical difficulties which it involved, the 'clearing system' was adopted by the different companies concerned. This system is one well known to bankers, who use it daily in the settlement of their business transactions with one another. A central 'Clearing-house' was established in London, to which a daily account is sent from each of the allied stations, containing a statement of the number of passengers that travel through; of parcels received or transmitted; of goods, cattle, private carriages, railway vehicles retained or forwarded—

* It affords a curious illustration of the slowness of some of the government operations, that the Postmaster-General's Report for 1864, ordered for preparation in 1865, did not actually make its appearance in print till 1866!

short, of all details of the traffic. These are classified, and the various debits and credits indicated by columns written in red or black ink; and thus the several liabilities having been ascertained, the payment of a few hundreds of pounds in balances, instead of the interpayment of thousands, serves to settle the whole. It has now become one of the largest commercial undertakings in England. Representatives from the several companies form the committee for managing the Clearing-house; and all the companies share the expenses of the establishment among them. At the central establishment in Seymour Street, Euston Square, near the North-Western terminus, there are nearly a thousand clerks, sorters, and messengers employed; while four or five hundred more are placed at the junction stations of the various companies' lines. The traffic that goes on *one* line only does not come under the cognizance of the Clearing-house, because there is in such case no division of proceeds between two or more companies. But when, for instance, a passenger goes from London to Edinburgh by the York or East Coast route, he travels over the territories of three different companies; and the Clearing-house has to determine exactly how much each company has to receive—so much to the Great Northern at King's Cross for booking, station accommodation, and use of carriage; so much to the North British for ticket taking and station accommodation at Edinburgh; and the residue divided among those two companies and the North-Eastern strictly according to mileage. So likewise, a ton of goods going upon the territories of two or more companies; station accommodation, collecting and delivering, hire of wagons and tarpaulins, are first deducted, and then the balance is divided among the companies according to mileage. All this work for all the companies is transacted at the Clearing-house by a system of book-keeping most admirably planned. Every penny paid by every 'through' passenger, or in reference to every 'through' parcel or bale of goods, is scrupulously accounted for, first by the companies to the Clearing-house, and then by the Clearing-house to each

company separately. Even the detention of a single tarpaulin at a station or dépôt, beyond a certain number of hours, is charged as a rent or demurrage to be paid by the withholding company. Every kind of service, in the eyes of the Clearing-house, has its money value, and is rigorously accounted for between company and company.

Accidents and Insurance.—There is no part of the railway system to which public attention is more directed than that of accidents to passengers. Many writers argue as if there might be *no* accidents on railways, and as if it were the duty of 'government' (that vague abstraction which is looked to as the hypothetical cure for all evils) to insure absolute safety for the public; but there is surely a mistaken notion involved in this assumption. So long as the companies are made heavily responsible in purse for loss of life and limb on railways, we may be certain that this is a better safeguard than any which the executive could administer. Who are more interested than directors and shareholders in doing the best that can be done in this matter? Is it a trifle to the South-Eastern Company to be compelled to pay £60,000 or £70,000 for compensation arising out of the Staplehurst accident? To lessen accidents is possible; to prevent them is utterly impossible, when we consider how numerous are the kinds of mishap to which railway operations are liable. First, as to the locomotive; a lever may be disarranged, an axle break, a tube burst, a valve fail, a spark from the funnel work mischief. Then the carriages; a tire may come off, an axle become overheated, or a coupling-chain break. Then the rails; the metals may twist or bend, a bar may snap, a joint spring up, a pin or fish-plate become loose, or the ballasting may have been washed away from beneath the sleepers by heavy floods. Then as for the working-staff—the engine-driver may keep up too high a speed, or overshoot the distance to a stopping stage; the guard may give a wrong signal, or no signal at all; the pointsman may turn the points the wrong way; the station-master may be wrong in signalling that the line is clear, or the police and porters wrong in permitting passengers to cross the line. Then on the permanent

works; an arch may 'give,' or a tunnel fall in, or an embankment slip, or a retaining-wall bulge. Then as to the passengers; they may get in or out of the carriages when the train is moving, or jump out heedlessly, or cross the line in spite of warning, or open a carriage door while the train is in full motion, or set fire to dresses or carriages by smoking.—Of course we know that such things *ought* not to be; that no one of them is absolutely unavoidable; but the truth is that some or other of them are sure to happen, from the very imperfection of human nature and human industry. If, in carrying 250,000,000 passengers, and many million tons of merchandise and minerals, there are 30 to 40 persons killed, and 500 to 600 injured, in the course of an average year—if this occurs (and it does occur), we naturally wish that the loss and suffering were less; but we must compare it with road travelling and sea travelling before we can really judge its relative merits and demerits.

The murder of Mr Briggs by Müller, in 1864, on the North London Railway, gave intensity to a demand that had often been made, for means of communication between guard, driver, and passengers. All the great companies caused their traffic managers to form a committee of investigation, to go with the utmost care into an examination of all the plans which had been suggested for means of effecting this communication. They examined no less than 196 distinct suggestions. Not one of the plans appeared to them fully satisfactory; but they made observations tending to produce practically useful results; and these improvements are being gradually introduced.

Meanwhile the public have the means of lessening to some degree the loss resulting from railway accidents. This provision is by the valuable system of *Railway Insurance*—a resource which, even if it had been thought of in the days of stage-coaches, would have failed because of the fewness of travellers. For threepence, a first-class traveller may insure his life for £1000, for any journey whether long or short; for twopence, a second-class traveller is insured £500; and for one penny, the third-class traveller gets £200; or smaller sums for injuries

which stop short of the destruction of life. Or the whole term of life may be insured by a single payment. This subject is well worthy of consideration by travellers, especially those whose means of existence might be stopped or diverted by any sudden casualty. In the excursion train which met with an accident at Rednal in 1865, there were no fewer than two hundred passengers who had in this way insured against accident; and for one of them, who had paid fourpence for insuring for the double journey, being among the killed, his family received £500. In the floods which worked so much mischief on the Devonshire railways in the beginning of 1866, the family of one of the sufferers received £1000, in return for the few pence which he had paid for a first-class insurance ticket.

Government and the Railways.—Much has been said and written in recent years concerning the expediency of placing the whole of the railways under government control, and even making them national property. As regards fares, the reform is advocated on some such reasonings as the following. Matters are now so arranged, that it is believed an average train does not carry more than 70 passengers. So much power is wasted, that what would carry 1000 does really carry only 70. As it is known that excursion trains at very low fares pay the companies sufficiently, and that exceptionally low ordinary fares during times of severe competition entail no very considerable loss, it is contended that companies might fill all their trains at very low fares, and yet obtain as much net profit as now falls to their share. If, by lowering fares (say) from £1 to 2*s.* 6*d.*, the companies only lose 1 per cent. dividend, then the present loss to the public may be reckoned thus: that we pay £13,250,000 more per annum than we ought to pay. The astounding sum is made out thus: that we pay £15,500,000 annually in railway passenger fares; that, if we paid only £2,250,000, the companies would lessen their dividends only 1 per cent. below the present average; and through that we pay £13,250,000 for nothing. Then comes goods-traffic. The average charge for conveying merchandise is about 29*s.* per ton per 100 miles; the

actual cost of carrying coals on the Great Eastern line was, a few years ago, estimated at 9*d.* per ton per 100 miles—*yielding a fair profit at that rate.* Therefore, the reformers say, as the country pays £16,000,000 a year for goods and mineral conveyance, and as £500,000 would yield a sufficient profit, there is an overcharge of £15,500,000, which, added to the overcharge on passenger-traffic, gives a stupendous total of £29,000,000.

The fallacies involved in this statement would soon be laid bare by a skilful accountant who had all the facts and all the vouchers fairly before him. The companies, we may be well assured, are not so stupid as wilfully and knowingly to throw away money at this rate. It may well be that a universal lowering of fares to a moderate extent, so as to fill the trains by inviting more passengers, would in the end pay the companies as well as at present, and please the public much better, but such extravagant estimates as those above mentioned are wholly untenable. As concerns the government, they have authority to purchase the railways, by virtue of an act passed in 1844, which empowers the Treasury to purchase, at their option, any railway after it has been at work twenty-one years: paying for it a sum equal to twenty-five years' purchase of the average of the last three years' dividend. Some writers now advocate to the full the exercise of this right, by the purchase of all the railways in the United Kingdom for (say) £500,000,000; then reduce the fares so excessively as to save the public the £29,000,000 a year above named; and then pay out of the taxes any deficiency in the interest for the five hundred millions. Others, more modest, simply advocate the reduction of fares to one-third their present amount. How the purchase-money is to be raised, and what guarantee we have that government could and would manage railways better than the existing companies manage them, are questions left very much in the dark.

Similar in some of its principles to this plan of compulsory purchase of all the railways by the government, is the scheme for the so-called 'Imperial Railway.' The scheme comprises the construction of three main lines, from London to Dover,

Holyhead, and Edinburgh, respectively. They would go nearly straight from end to end. The Dover line would have no intermediate station; the Holyhead line would have two intermediate stations at Stratford-on-Avon and Shrewsbury; while the Edinburgh line would have four—at Nottingham, Leeds, Carlisle, and Peebles (a branch from Peebles would go to Glasgow). The line would be broad gauge, with steel rails, and would cost £30,000 per mile. The speed would be not less than 60 miles an hour. There would be no third class, no return tickets, no special or excursion trains; but the first and second class fares would be so low that a passenger could go from London to Edinburgh for 20s. first class, and 15s. second. No goods, minerals, or short traffic would be carried; the receipts would be for long traffic in passengers, mails, and parcels. The returns are to be such as to yield 5 per cent. on the outlay; and the line is to be a national one, prevented, for ever, from amalgamation with any of the existing lines.—There is certainly an element of grandeur in the scheme; and there are many men in the railway world who believe that we ought to have distinct lines for the rapid through-traffic and the slow stopping-traffic; but this mode of picking away from the existing companies just the kinds of traffic which pay them best, is not likely to meet with much success in parliament.

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§ XI. RAILWAY PECULIARITIES IN AMERICA.

We shall know our own system all the better, if we have the means of comparing it with some of the very remarkable usages established in the United States.

In some respects, the arrangements and management of American railways are superior to our own. The carriages are from fifty to sixty feet long, resting at each end on a low four-wheeled truck, which, turning on a pivot, admits of sharp curves being passed without danger of running off the rails. The seats are placed across, on either side of a clear central space; and

the doors are at the end, a passage-way is thus obtained throughout the whole length of a train—an iron footplate serving to bridge over the space between the carriages. There is a positive advantage in this arrangement; the guard may be readily communicated with at any time in case of danger; and passengers, instead of sitting as though packed into a tea-chest, may pass from carriage to carriage, according as they may wish to change their seats, to look for a friend, or discover a conversable companion. A compartment at one end of each carriage is reserved exclusively for the use of women, and is fitted up with washing apparatus and other conveniences. In cold weather, the whole vehicle is kept warm by a stove, and lighted always at night by a lamp at each end. The seats are stuffed, and have padded backs, in all carriages alike, there being no distinction of first, second, or third class. The principle in America is to afford the same accommodation to all at the lowest profitable scale of charges. Such arrangements might not be generally acceptable in England; but the experiment would be worth trying, whether light, roomy carriages, of only one class, with stuffed seats and moderate fares, would find favour on the one hand, and bring profit on the other. Besides the advantages here indicated, the American carriages are but half the weight of those usually made in this country; consequently, the sixty or eighty passengers which each will accommodate are conveyed with economy of locomotive power and almost the minimum of 'dead-weight.'

There is yet another convenience peculiar to railway travelling in America which we feel bound to notice: the arrangements respecting luggage. The guard receives your trunks, bags, or boxes, attaches to each a numbered zinc label, and for each gives you a duplicate, and locks the whole in a special compartment. At the journey's end, you choose among the porters of the respective hotels waiting on the platform, hand your zinc labels to one of them, and walk or ride away, with the comfortable assurance that all your luggage will safely follow. Complaints about lost luggage are consequently rare. It will be said that the throng of passengers and press of business are so

much greater in England than America, as to prevent any possibility of similar arrangements. Here thousands travel short distances; there, hundreds travel long distances. Here, from twenty to a hundred trains a day from a station scarcely satisfy the demand; there, four daily trains suffice for the whole traffic. But might we not require that the most efficient and satisfactory arrangements should be formed where there is most work to be done? If we cannot do everything better than all the rest of the world, we ought at least to do as well.

In further illustration of some of the peculiarities of American railway travelling, we may quote from Mr W. Chambers's *Things as they are in America*: 'The train that carried me from Cincinnati consisted of six cars, including among the passengers a number of pedlers, who, with basket in hand, went from car to car, while the train was in motion, offering books and newspapers for sale. One of these travelling merchants went to work in a methodical manner. First, in making his rounds, he left with each passenger a circular descriptive and recommendatory of a particular book, and in due time returned for orders, which he executed on the spot. On some of the lines of railway, peddling in this and other forms has become so offensive, that it is now forbidden. Besides visits from the traffickers in books and newspapers, the passengers in the train were waited on every hour by a negro boy, supplying glasses of water. With a tin watering-pot in one hand, and a tumbler in the other, he respectfully addressed each person in turn. The providing of water in this manner seems to be part of the railway system in the United States. I, at least, saw few trains without a supply of water for passengers. Sometimes a vase and drinking glass occupy a spare corner in the car, and every one is left to take care of himself; but more frequently the water is carried round for general accommodation. As vases of water are likewise exposed for public use in many of the hotel lobbies, one is impressed with the belief that the Americans are the greatest water-drinkers in the world—whether as a matter of taste or necessity, I am not able to say.

'It is an unfortunate peculiarity in American railways, that certain States have adopted different gauges, so that a break necessarily takes place in passing from one to another. In the journey I was now performing, I had occasion to leave the state of Ohio; pass through about twenty miles of the state of Pennsylvania; and finish in the state of New York. In each of these states, the tracks were of a different width, and the shifting was anything but agreeable.'

The plan of the American railway companies has been to rest satisfied with single lines until the resources of a district are so far opened up, and capital thereby created, as to warrant the construction of double tracks. Only a few have as yet attained the dignity of double lines. It will be understood, therefore, that American railways are almost all only single tracks, and do not admit of trains passing each other, except at appointed stations. Sometimes a train has to stop for an hour till the arrival of the one in the opposite direction; but this, as with other inconveniences, is felt to be of inferior moment in comparison with having no railway at all. 'Contented at the outset with single lines, the projectors of railways are also satisfied with other simple and economic arrangements. Where bridges or viaducts are required, they are usually constructed of logs of wood, both for the upright supports and cross-bearers, applied in a rough state from the adze, without polish or painting. In some instances, there are long viaduct connections of this kind across lakes and inlets of the sea; and so little are they above the surface, that the trains seem as if running on the water. I seldom saw any ledges to these viaducts; and nothing could have saved the trains had they slipped from the track. In the more populous and advanced districts, we occasionally see viaducts across rivers, constructed at a considerable cost of stone and iron.' The general practice is to lay the rails on transverse wooden sleepers, of which there seems to be no scarcity anywhere, for they are generally placed not more than a foot apart; this abundance of sleepers apparently compensating for a want of proper ballasting or packing

with gravel. Little trouble is taken to dress the surface, to drain the sides, or to fence the lines. Where the railways intersect cultivated fields, or patches of a superior kind of pasture-land, the lines are enclosed with the usual zigzag rails; but in many places there are no fences of any kind, and the lines can be crossed by foot-passengers without challenge. At various places the railways proceed for miles through thick forests of tall trees and there the prospect from the windows of the cars is wild and solemn. Lofty pines, intermingled with birch and maple, rise like a wall on each side.

In reference to an item which is always so heavy in England preliminary expense, America is more fortunate. 'In most of the states, each railway company requires to have a special statute or charter, which is procured at an insignificant cost; all that is necessary being to shew that the proposed company is provided with means to carry out its undertaking. In several states including New York and Ohio, no special charter is now needed for a railway. A general railway law prescribes the rules to be followed by all corporate concerns; and within the provisions named, any railway company, if it has the means, may commence operations. There is thus, in reality, no impediment to the covering the whole country with railways; and this freedom is imparted on the solid ground, that each company best knows its own interests, and that nobody will be so foolish as to throw away money in making a railway, any more than in setting up a store, or building a factory, where it is not wanted. . . . Thus relieved of many expenses which weigh heavily on our system, and diminish profits, the American railway companies have the further advantage of getting land for nothing, or at very insignificant prices. In the western, or unimproved parts of the country, land for railways is sometimes given by townships, counties, or the state authorities, in order to encourage capitalists; and I heard even of instances in which the public contributed not only the land, but the earthworks.' As for cost of construction, wood for sleepers can, in many places, be had for the cost of cutting and preparing. To the great op-

prairies, wood as well as rails must, of course, be brought from distant quarters; but the expense of carriage is balanced by the comparatively light cost of earthworks. In these prairies, a railway may be carried 500 miles in a straight line on nearly a dead-level—the line stretching onward through grass and flowers without the slightest obstruction, and appearing to the eye like a zone girdling the earth.

Within all the principal termini, there are offices where tickets may be procured, and there are likewise, in every city of importance, general railway agency-offices, where tickets for a series of railways, *en suite*, may be purchased. There seems to be considerable competition among the agents who keep these establishments, in order to induce passengers to go by particular lines. Whether purchased from agents or at the stations, the tickets do not carry any date, further than the year in which they are issued. The practice is to sell all the tickets required in the route, although embracing the lines of several companies.

'An American conductor is a nondescript being, half-clerk, half-guard, with a dash of the gentleman. He is generally well dressed; sometimes wears a beard, and when off duty, he passes for a respectable personage at any of the hotels, and may be seen lounging about in the best company with a fashionable wife. No one would be surprised to find that he is a colonel in the militia, for "good whips" in the old coaching-time are known to have boasted that distinction. At all events, the conductor would need to be a person of some integrity, for the check upon his transactions is infinitesimally small. . . . . Hardly have the wheels made a revolution, when the door at one end of the car is opened, and the conductor begins his rounds. Walking down the middle, with a row of seats on each side, and each seat holding two persons, he holds out his hand right and left as he proceeds, allowing no one to escape his vigilance. All he says is "Ticket!" and he utters the word in a dry, callous tone, as if it would cost something to be cheerful. If you have already bought a ticket, you render it up to this abrupt demand, and a check-ticket

is given in exchange. Should you have followed the ordinary practice, and have no ticket to produce, the conductor selects the ticket you require from a small tin box he carries under his arm, and you pay him the cost of it, increased in price to the extent of five cents, as a penalty for having had to buy it in the cars—such fine being exigible, according to a printed notification on the walls of the station-houses. Having finished off in the car in which you are seated, the conductor opens the door at the further end, steps from the platform across a gulf of two feet, to the platform of the next car; and so goes through the whole train, till he reaches the van devoted to the baggage, where he has a kind of den for counting his money, and cogitating over his affairs. But as there is no rest for the wicked, so there is no repose for a conductor. Just before coming up to a station, he makes his appearance, and takes a deliberate survey of his customers, receiving checks from those who are about to depart. When the train is in motion again, the same ceremony is gone through—rather troublesome, it must be owned; but the conductor has a faculty for remembering who have checks for a long, and who for a short journey, and ceases to say "Ticket" more than two or three times to anybody. When it grows dark, the conductor does not trust to the lamp which lights up each car; he carries a lantern with a strong reflector, which enables him to scrutinise the equivocal bank-notes that may be tendered in payment. To enable him to perform this operation satisfactorily, the lantern is made with a tin hoop beneath, and through the ring the arm is thrust, so as to leave both hands disengaged. The checks which are distributed and collected by the conductor in the manner just explained, consist of narrow pieces of pasteboard about three inches long, and are of some use to travellers. On one side there is a list of the various stopping-places, with the intermediate distances in miles; and thus on consulting them, we are able to ascertain our progress. Information in this form is very desirable; for as there is a great deficiency of railway-officers at the stations, and

the conductor is usually out of the way when you want to ask a question, you are very much left to such knowledge as the checks and the American Bradshaw are able to furnish.'

The luggage arrangements seem to be well managed. Every train possesses a luggage-van (called a crate), and within an opening in its side is found a baggage-master, who takes charge of every person's luggage without any additional fee. On going up to the baggage-master with a portmanteau, he, on learning your destination, attaches a brass-plate, on which a number is struck, the plate being hung to a leather strap which he loops through the handle of the portmanteau. At the same time, he gives you a duplicate brass-plate, on producing which at the end of your journey, your portmanteau is rendered up. At all the principal termini, you are spared the trouble of even looking after your luggage. Just before arrival, the baggage-master leaves his van, and walking through the cars, asks every person if he would like his luggage delivered, and where. You give up your duplicate brass-ticket, the number of which is immediately entered in a book, with the name of the hotel you are going to; and, in half an hour or less after arrival, there lies your luggage on the floor of your bedroom. This trouble is requited by a small fee, which is paid by the clerk of the hotel, and entered in your account.

The common rate of speed is from twenty to thirty miles an hour. Two or three passenger-trains, each way per diem, is an ordinary allowance in the open districts; and from the general levelness of the country, the cost of working cannot be excessive. American engines 'fire up' with billets of wood, procured at a trifling cost, and stored in large stacks along the road, ready for use. From this rough fuel, when ignited, sparks rise in large quantities; but to prevent their egress, a capacious grating is placed over the chimney, and we do not hear of any damage being done by them.

Since the volume was written, from which the above extracts are taken, some of the more important railways in America have made a nearer approach to the European system, in the solidity of the works and the general rate of expenditure.

Annals of Railways from 1815 to 1866.

We cannot better close this chapter than by a rapid glance in the form of 'Annals,' at some of the more salient features in the progress of railways during the last wonderfully active half century.

1815. Sixteen Acts of Parliament for Railways passed between 1801 and that year.—Plain edged wheels adopted, to run on smooth iron rails.

1816. George Stephenson's first patent for a colliery railway locomotive.

1817—19. Only one new line of railway sanctioned by parliament in each of these three years; a few planned by private agreement.

1820. Rolled or malleable iron rails first substituted for cast iron.—Mr Gray's scheme for a national system of railways published.

1821. Stockton and Darlington Railway sanctioned by parliament, after much opposition.

1822—23. Not a single new railway sanctioned by parliament in either of these two years.

1824. Atmospheric railway tube first tried by Mr Mellish at Brighton.

1825. Opening of the Stockton and Darlington Railway, for passengers as well as minerals.

1826. Locomotives first used on Stockton and Darlington.—Act for Liverpool and Manchester Railway obtained.

1827. Passengers first conveyed on Scotch railway, Monkland and Kirkintilloch, and Glasgow and Garnkirk lines.

1828. Edge rails instead of flat rails adopted on French mineral railways.—First American locomotive constructed.

1829. Competition of locomotives, Liverpool and Manchester Railway.

1830. Opening of Liverpool and Manchester Railway, and final triumph of the locomotive.

1831. Newcastle and Carlisle Railway begun, first line from east coast to west.

1832. Dundee and Newtyle Railway opened, rising 540 feet in 11 miles, worked by rope traction.

1833. Act for London and Birmingham Railway obtained.—First suburban railway begun, London to Greenwich.

1834. First passenger railway in Ireland, Dublin to Kingstown.—The Belgian railway system commenced.

1835. Pinkus's Atmospheric Railway tried near London.—First broad-gauge line sanctioned.

1836. Railway commenced from Camden Town to Snowhill, and abandoned.—Acts for the Midland and Eastern Counties' lines passed.

1837. Great railway activity in parliament, forty-two acts passed.—Grand Junction Railway opened.

1838. Opening of London and Birmingham Railway throughout.—System of 'through tickets' established.

1839. First portion of broad gauge opened for traffic, London to Maidenhead.

1840. Blackwall Railway opened, rope traction and electric signals.—Clegg and Samuda's Atmospheric Railway tried.

1841. Board of Trade first obtained control over railways.—Brighton and Great Western lines fully opened.

1842. Railway Clearing-house system commenced.—Edinburgh and Glasgow Railway opened.

1843. First atmospheric railway opened for traffic, Kingstown and Dalkey.—South-Eastern and Eastern Counties' lines opened.

1844. First line sanctioned to cross the Border, North British.—Parliamentary trains established.—Eastern Counties' gauge changed from 5 feet to 4 feet 8½ inches.—First great railway amalgamation, the Midland.

1845. 'Battle of the Gauges,' in and out of parliament.—Highest prices known of the chief companies' shares.—Longest railway tunnel finished, at Woodhead, 5192 yards.

1846. The great Victoria Railway Bridge at Montreal planned.—600 railway bills in the House of Commons.—Broad-gauge express began to run from London to Bristol in 2½ hours.—London and North-Western Railway Company formed by amalgamation.

1847. Atmospheric system adopted on parts of South Devon Railway.—1000 railway acts passed down to this year, for 13,000 miles of railway, of which only 3000 open.

1848. £200,000,000 spent upon railways to this year.—Railway insurance system planned.

1849. Atmospheric system wholly abandoned.—Raising of the Menai tubes.—By this year, 160 railway companies had been amalgamated into 22.—First line planned for India.

1850. Coal traffic to London by Great Northern Railway organised.—Menai tubular bridge finished.—Tweed viaduct opened.—2000 railway stations at work in United Kingdom.

1851. Through tickets established between England and Ireland, including sea-passage.—Average distance travelled by every passenger found to be 18 miles, and average fare 25d.—Great Exhibition supposed to have brought £600,000 to the railway companies.—5000 persons brought by Great Western in one train of 150 carriages.

1852. The Alps first crossed by a locomotive at the Sömmering Pass.—T grand railway hotel opened at Paddington.—55 railway acts.

1853. Robert Stephenson determined the plan for the great Victoria Bri at Montreal.

1854. Works of Victoria Bridge commenced.—82 railway bills passed.— persons killed and 453 injured by railway accidents.

1855. The locomotive first crossed Niagara.—8050 miles of railway ope traffic in the United Kingdom at the beginning of the year.

1856. Estimated to be 32,000 miles of railway commenced in Europe which three-fifths finished and open.

1857. 104 railway bills brought in, and 84 passed.—Total capital of all companies, £346,000,000, of which £309,000,000 had been r and spent.—Experiments began on the great Mont Cenis tunnel

1858. 70,000,000 passengers travelled by railway in half a year, trave 1,050,000,000 miles, and paying £13,000,000 for their tickets.- sum of £23,000,000 spent by this time on railways in India.

1859. Victoria Tubular Bridge opened.—The Rhine crossed by railwa Cologne.—Finishing of Brunel's Albert Bridge over the Tamar.

1860. About 10,000 miles of railway open in the United Kingdom,- 28,000 in the United States, at the beginning of the year.— railway acts passed in the last ten years.

1861. Boring of the Mont Cenis tunnel commenced at the south end Railway bridge over the Ebro finished.

1862. Bridge over the Rhine at Mayence opened.—First underground r way (Metropolitan) opened.—Mont Cenis tunnel at north end be

1863. 205,000,000 passengers conveyed on 12,000 miles of railway. 4,700,000 trains, which ran 117,000,000 miles.—£32,000,000 p for conveyance of passengers, live-stock, goods, and minerals.

1864. Capital spent on railways in the United Kingdom, £425,000,00 296 railway bills came before parliament, of which 201 passe 417 miles of new railway planned for the metropolis alone.

1865. Railway *over* Mont Cenis commenced.—Pneumatic railway under Thames sanctioned.—Railways open in the United King increased to 12,400 miles.—250 new railway acts passed.

1866. The Scotch lines from Carlisle to Aberdeen, all under one company amalgamation.—Continuous rail open from Penzance, near L End, to Bonar Bridge in Sutherlandshire, 845 miles.—Openin Cannon Street Station.—Ascertained expenditure of £4,000 on two miles of railway to Cannon Street and Charing Cr including the bridges and stations.

CHAPTER II.

STEAMERS.

§ I. SHIPS OF EARLY NATIONS.

TRAVELLING by river or sea would naturally suggest itself to all except the inhabitants of regions in the heart of a large continent. The very floating of trunks of trees on the water would give a hint to the first shipwrights; while a little study of the movements of a fish, combined with the peculiar shape of the fish itself, would furnish something like a pattern for the prow, the bows, the quarter, the run, the stern, the oars, and the rudder of a floating vessel. A single plank to which the navigator clings, like the surf-swimmers of some of the Sandwich Islands; a hollowed trunk of a fallen tree; beams or planks lashed together to form

a raft; the pottery-floats of Egypt, consisting of earthen vess covered with a flooring of bulrushes; planks of acanthus-woo lapped over and pegged like the slates of a house-roof, wi papyrus leaves, to form a sheathing and an awning; a framewo of willow, covered with skins; wooden-ribbed vessels, w similar skin-coverings; a canoe with a skin-deck, which wr round and encloses the lower part of the navigator's body; double canoe of two hollowed trunks, with planks stretched acr from the one to the other; long poles tied together with wh sinews, and covered with sea-dog skins—all were primitive fo of boat, and most of them could probably still be found am the ruder tribes of the earth. In countries intersected numerous rivers, the traveller adapted himself to land and wa travelling with equal facility; his ass carried the boat by la his boat carried the ass by water.

To make a wind-bearing surface accommodate itself to particular direction in which a navigator wished to move, an achievement dependent on many experiments. Whether have one, two, or more masts; whether to fasten one or mo sails to each mast; whether to carry the masts to a great or small height, and to make the sails large or small; whether sails should be square or triangular; whether to cause them veer round the mast, or to slide up and down it—were po that could only be determined by patient study. One by o the component elements of a complete ship—the deck, rudder, the anchor, the cables, the rigging, the cabin—w invented, by gradations, which it would be vain to think of tracing.

Commerce and war have ever been the most active purs of nations; and commerce and war in early times led to division of ships into two classes, planned in special relatio the services which they were intended to subserve. The ships of the ancients, the *galleys*, *triremes*, and other variet were propelled by oars rather than sails; there were not on long rows of oarsmen, but sometimes two or more tiers one ov another. Many of the war-galleys had beaks or project

prows, constructed for the same purpose as the *rams* of later days ('There is nothing new under the sun!')—that of dashing into the enemy, and shattering his hull; while, on the other hand, strong timbers were so placed as to guard against a retaliation by similar means. On these vessels were stages, platforms, and turrets of various kinds, to be occupied by archers, javelin-men, slingers, and men provided with heavy stones to let fall upon the enemy. The commercial ships, in those early days, were made shorter and rounder than the war-galleys, to enable them to carry more cargo, passengers, and luggage; they were very flat-bottomed, and drew but little water.

The Greeks are credited with the first employment of decks over the ranks of rowers in the galleys, to facilitate the manœuvres of armed men. The Phœnician and neighbouring nations employed for commercial purposes ships without keels, broad in beam, flat in floor, and rounded at the ends. Two motives actuated the builders in gradually introducing keels—to facilitate the fastening of the bent ribs which formed the framework, and to enable the ship to cut more swiftly through the water. The planking which covered the frame was fastened to the ribs by iron bolts; and there is reason to believe that the dovetailing of short timbers, to make a strong timber of greater length, was not unknown to the early shipwrights.

The early nations gave class-names to their ships depending on the countries to which they belonged, the ports whence they sailed, or the purposes to which they were applied. The individual names, given to single ships without any regard to class or kind, were as fanciful and heterogeneous in ancient times as at present—when we find the names of gods and goddesses, saints and martyrs, popes, emperors, kings and queens, princes and princesses, naval and military heroes, poets, dramatists, novelists, painters, sculptors, actors and actresses, musicians and singers, fairies, furies, magicians, spirits of good and of evil, plants, flowers, trees, fruits, gems and precious stones, planets and satellites, asteroids and stars, countries, rivers, seas, oceans, islands, lakes, mountains, towns, counties—all brought into requisition.

The ships with which the Britons opposed the landing of Cæsar were flatter than those of their opponents, fitted for sailing in tidal harbours and along shoal coasts. They were very elevated at prow and poop, or head and stern, a precaution deemed necessary against stormy seas. The Saxon pirates who troubled the North Sea or German Ocean, had ships with wicker frames and hide-sheathing; they differed from the coracle in having wooden keels, which facilitated their more rapid progress through the water. At a later period the Anglo-Saxon ships were single-masted; they had a square sail, a curved bottom or floor, and the prow and poop much decorated. Under Canute, the Danish vessels were on some occasions so large that they would carry a hundred armed men each; the mast and other parts of the vessel were often sumptuously decorated.

From the time of the Norman invasion, the advance of ship-building in England was steady and continuous. The Norman galleys, 900 in number, which brought over William and his valorous companions, were small, scarcely accommodating twenty men each. The ships with which Richard Cœur de Lion gained notoriety in the seas around France and in the Mediterranean, appear to have been the largest and best of those days. Under the names of *busses* and *dromons*, these vessels were, in some instances, three-masted, spreading a greater area of canvas to the wind than had before been known. About the time of Edward III., English war-vessels had undergone a considerable change, so as to resemble rather a modern ship than an ancient galley. The length was reduced, the prows and poops raised to a greater height, the frames of the hull more skilfully constructed, and the boards forming the outer planking lapped instead of joining with flush edges. Two masts were often used; and the square sails and the yards were planned for reefing and unreefing much more rapidly than had been possible in the older galleys. A bowsprit was now for the first time used. Meanwhile, the galleys of the Mediterranean underwent little change. The modern Venetian

gondola is an application of the galley of those days to the canals and narrow channels that separate the small islands whereon the city of Venice is built.

When gunpowder was introduced into naval warfare, the sides of ships required to be higher than before, to give space for the guns and gunners. At first, the guns were fired over the side or gunwale; but an improvement was effected by making port-holes through which the shot might pass. The top timbers or upper part of the sides being made usually to incline inwards, gave a lumpish, heavy appearance to the *galleons*, as such modified galleys were termed. The Venetian *galleas* was a still larger vessel of the same kind, sometimes with three masts, and carrying guns at the head and stern as well as on the broadside. One by one, various improvements were introduced in the forms and fittings of ships. The forecastle, the 'castle of the king,' was lowered, to render it more useful as a deck; the pilot, originally perched on a stage near the topmast, was furnished with a standing-place of less perilous kind; the bowsprit, having been found useful as a means of supporting or fastening additional sails, came into general use; three masts became common, and four were not unfamiliar; while the comfort of the officers and crew was studied by the construction of a cabin near the stern, and a ruder cabin under the forecastle. Gradually the size of merchant-ships as well as of ships-of-war was increased. Even before the end of what we are accustomed to call the middle ages, Bristol sent forth trading-ships called *carricks*, sometimes six or eight hundred tons burden.

§ II. VOYAGES OF EARLY NATIONS.

The early navigators were timid, in fear of dangers which they had not learned to conquer. To sail only in summer; to start only when winds and waves were favourable; to invoke the special protection of some deity or deities, when a voyage was about to

be commenced; to regard with superstitious hopes or terrors numerous omens which cannot even be imagined at the present day; to draw up and anchor in some cove at night, rather than brave the dangers of the open seas after dark; to keep within sight of the shore; to land frequently for provisions—these were the maxims which governed them. It was only after numerous discoveries in science and inventions in art had been made that mariners ventured out of sight of land. When it became known how regular in their revolutions are the sun, moon, planets, and stars, men were able to lay down rules for determining the course of a ship at sea, and the distance and bearing from known ports and headlands, by the relative positions of the heavenly bodies. Many special rules—the appearance of sea birds, the prevalence of particular kinds of fish, the surges and breakers that denote the vicinity of the coast, the appearance of the sky and clouds, the vicinity of headlands and coast-cliffs, the shallowness and nature of the soundings, sudden changes in the temperature of the air or direction of the wind—were signs that possessed much value before the compass was brought to the aid of the mariner.

Whether the inhabitants of China or India knew anything of navigation earlier than the dwellers on the shores of the Mediterranean, we have no certain means of judging; but the most ancient reliable records certainly give the precedence to the latter. The Phœnicians and Carthaginians were early navigators of the Mediterranean; and the merchants of Tyre and Sidon are credited with the trick of exaggerating the dangers and horrors of the seas, as a means of deterring others from embarking in enterprises which would disturb a profitable monopoly. There is historical testimony to the voyage of Scylax, at the desire of Darius, down the Indus, westward across the Indian Ocean to the African coast, and up the Red Sea; to the attempt of Sataspes, in the time of Xerxes, to sail down the west coast of Africa; to the voyages of two Carthaginian fleets, one under Hanno down the west coast of Africa, the other under Himilco, up the west coast of Europe; to the voyage of Pytheas, the

Massilian, up the Atlantic coast as far as Britain, Norway, and Iceland; to the voyage of Nearchus, at the command of Alexander, down the Indus, across the Indian Ocean, and up the Persian Gulf to the mouths of the Tigris and Euphrates; and to the abortive attempt of Eudoxus to circumnavigate Africa. Opposed by the hostility of the Egyptians and Ethiopians on the western shores of the Red Sea, and of the Syrians and Arabians on the eastern, the Phœnicians tried to get across the Isthmus of Suez to the Red Sea by selecting some landing-place on the Mediterranean coast, and establishing a system of land-transport thence across the isthmus to Suez. Two sets of voyages were thereby placed in aid of each other, one from the Asiatic to the African coasts of the Mediterranean, the other from Suez down the Red Sea to the Indian Ocean.

Discoveries of various natural phenomena were of vast aid in developing navigation. The Roman masters of Egypt, in the time of Claudian, are said to have been the first to avail themselves of the *monsoons*, a modification of the trade-winds, in traversing the Indian Ocean. Another discovery, arising out of the knowledge that the earth is globular, was that imaginary lines of latitude, crossing imaginary lines of longitude, will serve to define the positions of places on the earth's surface, enabling mariners either to lay down such places on maps and charts, or to describe them by a few numerals. Ptolemy was the first to render this method useful about the second century of the Christian era.

During the middle ages, navigation groped its way, like most of the arts, slowly and laboriously. The Arabs, for some centuries, took the lead, inheriting what was left of the enterprise that had formerly distinguished some of the nations bordering on the Mediterranean. They established regular voyages between the Persian Gulf and India, to some extent competing with the Red Sea trade. They seem to have rounded Ceylon, and visited ports on the eastern coast of India. Two centuries later, they reached as far as the southern confines of China, from which vast and rich empire stores of merchandise

were brought to Bassora, there to be exchanged for European goods. An account is extant, in the works of Edrisi, of an expedition made in the twelfth century by some Arabs, which is believed to denote the fact that the mariners reached the Azores and Canary Islands.

The nations and states which were gradually formed in Italy out of the wreck of the old Roman empire, grew, in some instances, to great maritime importance. Venice was the most prominent among them. The Venetians began by sending out trading-ships to neighbouring ports; then they sent war-galleys to accompany and protect the trading-ships; and thus they developed a controlling power throughout the eastern half of the Mediterranean. Under the famous doges, Micheli and Faliero, fleets of two hundred war-galleys were sent out to take part in the Crusading expeditions; and a third fleet of the kind defeated the Byzantine fleet under Barbarossa. Their success in trade enabled the Venetians to bear the cost of these armaments. In the twelfth and thirteenth centuries, Venetian ships brought the treasures of the East—gold, silver, silk, spices, diamonds, aromatics, drugs, dyes—to England, at a time when our own commercial marine was barely developed. The Venetians, though occasionally equalled by the Genoese, continued to be the dominant maritime power in the Mediterranean until the latter half of the fifteenth century; when the discovery of new ocean routes by the Spaniards and Portuguese gave a formidable check to Venetian leadership in the interchange of European commodities for those of the distant East.

These new ocean routes mark the most important epoch, perhaps, in the history of sea-travel. The thirst for wealth has always been the leading motive to geographical discovery; and it was not less observable in this instance than in others. The Spaniards and Portuguese resolved to search for a new route to India by way of the Atlantic and Southern or Indian Ocean. The magnet or loadstone, by whomsoever discovered, became regularly employed as a nautical aid in the fifteenth century, and justified mariners in departing and remaining out of sight

of land with a boldness not permitted to those who guided their ships merely by observation of the stars; and about the same time various instruments were invented for taking altitudes and measuring arcs of the meridian and horizon. The Portuguese, under the direction of Prince Henry, extended their knowledge of the West African coast as far south as Cape Bojador. Towards the close of the century, Bartholomew Diaz made the celebrated voyage by which he discovered the 'Cape of Storms,' a name changed by John, king of Portugal, to 'Cape of Good Hope.' The still more notable voyage of Vasco de Gama finished the work done by Bartholomew Diaz. Just before the close of the century—that is, in 1497, 1498, and 1499—Vasco not only doubled the far-famed cape, but spanned the ocean from thence to India; giving to the Portuguese, in the magniloquent potency of the pope's rescript, supreme possession of all the countries that might be discovered in the Indian seas.

The Spaniards marked out for themselves a scene of maritime glory in another region. They sought westward across the Atlantic, rather than round the Stormy Cape. Columbus found favour with Ferdinand and Isabella in regard to a plan he had formed for discovering new lands. He unquestionably visited islands in the so-called West Indies, and coasts in Central America, which had never before been seen by Europeans; and his narrative of these expeditions, which took place in 1492 and 1493, shewed clearly enough that a pathway could be traced across the broad Atlantic, even with the small and ill-fitted ships of those days. Then ensued the discovery of Newfoundland, in 1497, by Sebastian Cabot; the voyage to Brazil and the mighty river Amazon, in 1499, by Pinzon; the adventurous voyage of Bilboa, in 1503, to Darien, and the journey across the isthmus, till he gazed upon the majestic Pacific Ocean; the discovery by Magellan, in 1520, of the South American strait which bears his name; the bold voyage made by some of Magellan's companions directly across the Pacific to the Philippines, and so home round the Cape of Good Hope—the

first real circumnavigation of the globe; the discovery by Amerigo Vespucci of new portions of the South American coast; and the voyages of Ponce de Leon to Florida, and of Girjalva to Mexico. It will thus be seen, that while the Portuguese honourably distinguished themselves by making the daring voyages which established an eastward route to India round the Cape of Good Hope, the Spaniards were at least equally active in western research across the Atlantic and Pacific Oceans.

England was of course not inactive during these centuries, though her maritime daring did not so early manifest itself in distant seas. Of the discovery of America in the ninth century by the 'hardy Norsemen,' we know too little to speak with certainty; nor, indeed, throughout the long range of centuries down to the days of Frobisher, Drake, and Cavendish, was there any great amount of distant geographical discovery or ocean-voyaging made by the English or their neighbours. Drake was the first Englishman—Magellan's companions having been the first of any country—who circumnavigated the globe; he went round Cape Horn, followed the west coast of America as far up as California, crossed the Pacific to the Spice Islands, and so homeward round the Cape of Good Hope. Davis, Baffin, and Hudson made their adventurous attempts to round the northern extremity of America as a means of reaching the Pacific Ocean and the Indies; they failed, but they discovered the straits and bays which have been named after them.

All that has been done during the last three centuries to increase our knowledge of the earth's surface by long voyages in sailing-ships, has been but the legitimate filling-up of an outline already prepared. Little by little, all the coasts of the new and old continents have been laid down in our maps, together with those of the Australian and Polynesian groups of islands, and almost countless islands in other oceans and seas. Ship-builders had every inducement to make their ships both roomy and swift, that they might accommodate a large amount of cargo, and might, at the same time, return more profit to

completing their voyages in a short period. Hence the splendid Indiamen built in the old days of the East India Company, and the still more splendid American 'liners' that ran (and still continue to run) from London and Liverpool to New York, and the Aberdeen 'clippers' that have worked so well in the China and Australia trades. One of the grandest sights on the sea must be a first-class sailing-ship, with all canvas spread, borne swiftly and steadily by the trade-winds across the mighty Pacific.

Perhaps the most exciting work in which such ships are ever now engaged is the maintenance of an ocean-race of 15,000 miles, such as that which is run by the China tea-ships in the summer of each year. The London tea-brokers, in order to get the new crop into the market as soon as possible, offer a prize of £500 to the officers and crew of the first tea-laden ship which reaches the Thames. In 1866, nine such ships left Foo-chow-foo between May 29 and June 6; they were not very large, varying from 686 to 853 tons register; but they were all very fast, five being Clyde built, three Aberdeen, and one Liverpool. Sometimes the ships sighted each other, sometimes they were mutually invisible; but every yard of canvas was spread whenever the wind permitted. It was a wonderful race; for the *Taeping*, *Ariel*, and *Serica* all entered the Thames in one day (September 6)—nay, all between 9·45 and 11·30 in the evening, the other six ships being further from the winning-post.

§ III. RISE OF STEAM-NAVIGATION.

UNQUESTIONABLY, the greatest of all improvements in navigation—next, perhaps, to the introduction of the mariner's compass—was the application of *steam-power* as a substitute for sails. Oars are of use only so long as there are hands available to wield them; sails are available only so long as there

is a breeze to fill them; but a steam-engine is never tired, and works on whether there be wind or not.

Attempts were made to move boats by revolving paddles long before the steam-engine was invented. The ancient Egyptians are believed to have navigated boats on the Nile by causing paddle-wheels to be rotated by oxen; and wheel-boats, more or less similar, were used by the Romans and the Chinese. Prince Rupert worked a wheel-boat on the Thames by the aid of a horse; and Captain Thomas Savery effected the same thing by rotating a wheel through the medium of manual labour. A Swiss pastor named Genevois, in 1759, hit upon an idea that the web-feet of aquatic birds might advantageously be imitated. Earl Stanhope, some years later, sought to improve upon the project by applying duck-feet paddles under the quarters or sides of a boat; but he could not induce his duck's feet to fold with sufficient ease at the right moment—a fault which caused them to retard the progress of the boat.

It is now pretty well agreed that no one person solely invented steam-navigation; there were many successive inventions towards which many minds contributed. A claim is put forward, on the authority of a manuscript by Samancas, to the invention of a steam-boat by Blasco de Garay, a Spanish sea-captain, so far back as 1543; but both internal and external evidence tell against its authenticity. Another claim has been put forward for the eccentric Marquis of Worcester, whose *Century of Inventions*, written in 1665, contains many descriptions or 'propositions,' which would certainly bear the interpretation of a steam-engine with a piston and a lever employed to propel a boat; although there is no evidence that he ever constructed such an apparatus. Papin is considered by the French to have invented a steam-boat; and so he may in theory, but not in practice. Dr John Allen, in 1730, described a plan for propelling vessels by forcing a stream of water out of a pipe at or near the stern; steam being employed to force the water, and the vessel moving by the reaction produced. Jonathan Hulls obtained a patent in 1736 for a tug-boat worked by

steam; the steam-engine communicated its power by means of a rope to a kind of paddle-wheel attached to the vessel which was to be towed. In 1774, the Comte d'Auxiron tried a small steam-boat on the Seine; but it had not sufficient power to move the paddles properly. In 1775, Perier constructed a boat, in which a little engine of one-horse power worked two paddle-wheels, which drove the boat slowly along the Seine. In 1781, the Marquis de Jouffroy tried a boat of much larger dimensions on the river Saône; it was 130 feet long, had two paddle-wheels, and was more effective than any which had preceded it. And in 1796, M. des Blancs, a watchmaker at Trevoux, obtained a French patent for a steam-boat, but never worked it.

We now come to Scotland, to which the real, effective, practical invention of the steam-vessel may be more justly attributed than to either England or France. Mr Patrick Miller, a banker at Edinburgh, about the year 1787 invented a double-boat, with a paddle-wheel in the middle; but it was not a *steam*-boat, for he employed a man to work the wheel. Another double-boat, with two men to work two wheels, ran a race against a fast-sailing custom-house boat. The £3000 which Mr Miller spent in these inventions was not wasted, seeing that they led immediately to important modifications. Mr James Taylor, a tutor in Mr Miller's family, had assisted him in his experiments, and now suggested the application of a small steam-engine to supersede the labour of a human wheel-turner. Mr Miller, entering into the plan, employed William Symington, a mining-engineer at the Wanlockhead lead-mines, to make the engine. A little one-horse power steamer (still preserved in the Andersonian Museum at Glasgow) was built, and was propelled at a rate of five miles an hour upon a lake near Mr Miller's house at Dalswinton in Dumfriesshire; it was a double-boat, with the engine on one side, the boiler on the other, and the wheel between them. This experiment, made in 1788, encouraged Mr Miller to buy one of the boats used on the Forth and Clyde Canal; he employed Symington to plan a twelve-horse power engine suitable for it, to be made by the Carron Iron

Company. It was so far successful, that the steam-boat tugged a heavy load on the canal at a speed of seven miles an hour. This was in 1789. Nothing further was done by the three ingenious men conjointly. Symington, however, when, after several years' service as an engineer, he had advanced in his profession, made and engined a boat in 1802, which drew two laden barges on the Forth and Clyde Canal, each of seventy-two tons burden; it went twenty miles in six hours, against a very strong wind. The steamer was short, and had a horizontal engine, which worked a single paddle at the stern by means of a connecting-rod and crank. Amongst those who visited and inspected his vessel was Henry Bell, whose ingenuity we shall have occasion to notice presently.

Attention must now be directed to what was achieved by Americans towards the development of steam-navigation. In 1783, Mr Fitch propelled a steam-boat on the Delaware by paddles, and made strenuous efforts to get his invention taken up by the authorities. He was unsuccessful; but he prophesied truly in saying that 'the time will come when steam-power will be employed for crossing the Atlantic.' In 1787, Mr Rumsey devised a boat about fifty feet long, in which a steam engine pumped in water near the bow, and drove it out near the stern: the boat moving by the reaction thus produced. With this he drew a boat with a weight of three or four tons, at four miles an hour, up and down the Potomac. Rumsey afterwards proposed a mode of employing steam-power to drive a pole obliquely against the bed of the river, and so propel the boat. The next American in the field was Robert Fulton, who was in Paris about the time when M. des Blancs was engaged upon his patents. Like him, he experimented on the possibility of propelling a boat by means of paddles attached to an endless chain, the chain being stretched over two wheels projecting from the sides of the boat. Fulton, however, soon abandoned this plan, and adopted a wheel instead of a chain. In or about 1799, Fulton entered into a new project with Mr Livingstone; they placed a large steam-boat on the Seine, which, breaking in

the middle, through weakness of construction, caused them to build another, much larger and stronger. Fulton paid many visits to England and Scotland, and was present at some of Symington's experiments. Symington afterwards, in a written narrative, states that Fulton obtained all available information from him, and adopted his contrivances without making the slightest acknowledgment of them. Shortly before this period, John Stevens, of Hoboken, New York, built a boat twenty-five feet long, with a small engine and boiler of extremely ingenious construction; the tiny steamer went along at four or five miles an hour. In 1804, Oliver Evans, another American, formed a steam-boat by attaching a paddle-wheel to a sort of steam-dredge, to which he gave the grandiloquent name *Orukter Amphibolos!* In 1807, Fulton made a new steamer, with engines by Boulton and Watt. This vessel, the *Clermont*, astonished every one by making a voyage up the Hudson from New York to Albany, a distance of 150 miles, at the rate of five miles an hour. It was the first voyage of such a length ever made by steam-power. The Albany people had never seen a steamer; and the new-comer, seen in semi-darkness, was described as 'a monster moving on the water, defying the winds and tides, and breathing flame and smoke.' Dry pine-wood was used for fuel, and this sent forth flames from the funnel, which greatly increased the terrific appearance of the monster. The *Clermont* was 138 feet long, 18 wide, 7 deep, 60 tons burden, with iron paddle-wheels 15 feet diameter—in short, it altogether eclipsed everything that had yet been produced in this class of naval architecture. The *Clermont* made many voyages to and fro in that year and in 1808; the voyages were *bonâ fide* commercial transactions—passengers in good number paying high fares. Stevens was the first to make a *sea*-voyage by steam; he went in a new steamer from New York to the Delaware, and introduced so many important improvements as to attain the astonishing velocity of thirteen miles an hour on that river.

Once again we return to Scotland, to notice the useful labours of Henry Bell. Having known Miller, Symington, and Fulton,

and collected a good deal of information on the subject, he caused a steamer to be built on a model furnished by himself. It was a tiny affair, only 40 feet long, $10\frac{1}{2}$ wide, 25 tons burden, fitted with a steam-engine of three-horse power, and carrying paddles; there was a single cylinder, the piston acting on a crank which moved the paddle-wheels; and the paddles themselves were something like malt-shovels. Mr Bell called his little bark the *Comet*, because it was built in the comet year, 1811. Being proprietor of a hotel and bathing-house at Helensburg, he conceived the idea of employing his steamer to bring visitors to and from Glasgow. The *Comet* began to run regularly in 1812, and continued to ply throughout the summer. Other steamers soon eclipsed it; but the world must not forget that the *petite* steam-boat was the first that plied in Europe for regular passenger traffic. In 1813, Mr Hutchison placed the steamer *Elizabeth* on the Clyde; it was a well-built craft, able to carry a hundred passengers, at a speed of seven to nine miles an hour, and at a charge one-third of the coach-fare from Glasgow to Greenock. The scheme was so successful, that steam-navigation on the Clyde became, thenceforward, firmly established. About the same period, Mr Lawrence introduced a small steamer on the Severn, and Mr Dawson another on the Thames. In 181[illegible] Mr Dodd was the first to make a sea-voyage by steam in Europe, and a very perilous voyage it was. He undertook to bring round, from Glasgow to London, a small steamer of 75 tons burden, and 16-horse power, called the *Thames*; he worked his way by steam and sail, and encountered terrible difficulties in the Irish Sea. From that time, the progress of steam-navigation was exceedingly rapid. In 1820, England had 17, Scotland [illegible], and Ireland 3 steamers. The regularity, speed, and safety with which the voyages of these vessels were made soon pointed them out as the best conveyance both for passengers and mails. In 1821, they were employed on the latter service between Dublin and Holyhead, and between Calais and Dover.

§ IV. BEGINNINGS IN OCEAN-STEAMING.

AFTER the steam-boat had thus passed through the various stages of infancy and childhood—had tried its strength on English rivers, in the Irish Sea, and in the British Channel—men began to ask, was it not strong enough and reliable enough to do more? Could it not cross an ocean as well as a channel?—take letters, and men, and merchandise to America, India, and Australia, as well as to Ireland and France? In this question were involved considerations of the highest importance to all the world, but particularly to Great Britain, from her extensive foreign possessions. With the exception of the United States, all the colonies planted by the British remain part of the empire; while Spain and Portugal have lost nearly all those rich territories—extending over the fairest portion of the great American continent—that at one time acknowledged the sway of the Houses of Bourbon and Braganza. The foreign possessions of France are insignificant; and of the other nations of Europe, the Dutch alone possess a territory abroad greater than they have at home. It is therefore scarcely a figure of speech to say, that the British Empire is the greatest in the world, for it embraces a territory of nearly 6,000,000 square miles, and a population of 200,000,000—or about one-eighth of the land, and one-seventh of the inhabitants, of the globe. Nor is it less true to say, that on these great possessions the sun never sets, for they are scattered all over the world—in tropical Africa and Asia, in the temperate zones of both hemispheres, and among the islands of every ocean; and whether occupying a rock, as in Gibraltar, an island, a continental province, or a continent itself, as in Australia, their geographical position fits them well for upholding the power of the empire.

The proud position of Britain among the nations, the necessities of her foreign trade, and the wants of her colonies and dependencies, apart from all other considerations, rendered it fitting and natural that she should lead the way in maritime enterprise. Nor has she failed in this high task; for within thirty years since the question was first mooted, she has established lines of gigantic steam-vessels that are now traversing with regularity and safety every ocean.

When it was first proposed, about 1836, to cross the Atlantic by steam-power alone, the idea was deemed illusive. Some of the most distinguished scientific men in the country gave a verdict against it, and prophesied its failure in no equivocal language. At the command of these philosophers, all kinds of spectres rose up from the Atlantic Ocean to terrify the daring men who had determined to make the attempt. The action of the paddle-wheels on the water—the waves, and storms, and currents of the Atlantic—and the quantity of coal necessary to be used, were all made the subjects of nice calculations such as no person could dispute; and the theorem they all tended to prove was, that the project was utterly impracticable. To men who made no pretence to be philosophers, the difficulties in the way were self-obvious. The distance to be traversed was at least three thousand miles of clear ocean, with no intervening land where a vessel might run in for shelter or supplies. Mariners know well that the Atlantic is not only frequently agitated by terrific storms, but that its currents run across the track of any vessel sailing between England and America. The effect of these currents is such, that while the fine packet ships called 'liners,' by which communication was chiefly maintained with America, could sail from New York to England in about twenty days, the time occupied by the same vessels on the voyage *out* to New York was usually thirty-six days. The estimated quantity of coal necessary to propel a steam-boat across the Atlantic seemed to stamp the project at once as impracticable. It was no doubt true that, in 1819, a steamer called the *Savannah*, of 350 tons, had performed the voyage between

New York and Liverpool in twenty-six days; but this vessel used sails as well as steam, and she was a week longer on the voyage than the time usually occupied by the 'liners,' so that her performance was neither a precedent nor a guide. But there were steam-ships employed on government service in the Mediterranean and on other coast-stations, from which data were obtained serving to shew that, to accomplish a voyage of the same length as that across the Atlantic, two tons of coal would be used for each horse-power of the engines—that is to say, if the engines are of 300 horse-power, they would consume 600 tons of fuel before they reached the terminus of a three-thousand-mile voyage. But a spare supply must always be carried, to provide against accident or delay; so that the quantity in the supposed case must be raised to about 700 tons. On the other hand, it was said that if the tonnage of the vessel were made more than four times its horse-power, the latter would be inadequate to its propulsion at the ordinary rate of steam-ships. The tonnage, therefore, of the supposed vessel could not exceed 1200; and after making allowances for cabins, ship's stores, machinery, boilers, &c. the space left for fuel would not contain more than 500 tons, which would all be consumed before the vessel arrived within 500 miles of the American coast. And so the conclusions went forth unchallenged, calling up vivid pictures of a magnificent steam-boat suddenly stopped in its career for want of fuel, and rolling like a helpless log on the ungentle bosom of the great Atlantic!

Among mercantile men, again, another great question arose—Would the speculation pay? It is well known that a steam-boat costs much more than a sailing-vessel, both in construction and working: the sails of the latter are filled by wind, for which nothing whatever is paid; but not an arm of the machinery of the former will move until the furnace has been fed with coal, never to be had, even at the cheapest ports, without a considerable outlay of money. The officers and men, too, must be more numerous; while the machinery, boilers, and fuel occupy a very large space that in sailing-vessels is filled with goods. The

number of passengers who crossed the Atlantic every year was certainly very great: in 1836 (the time at which the project was discussed) the number might be estimated at about 60,000; but all, or nearly all, of these were emigrants, utterly unable to pay such charges as the owners of steam-vessels would be obliged to make. The trade between this country and America was certainly most extensive; nevertheless, in carrying the goods bought and sold, no steamer could compete successfully with sailing vessels. Unless, therefore, a remunerative passenger traffic could be created by the certainty and speed of the communication, and a favourable contract obtained for carrying the mails, it was quite evident that the speculation would *not* pay.

There were, on the other hand, mercantile considerations affecting the commerce of the country, which rendered it clear that if the regular navigation of the Atlantic by steam were practicable, it was essential to British interests. Nothing is so important in extensive commercial transactions as early and regular intelligence, and a quick and speedy transmission of orders and goods. Judging from what steamers had already done, it was reasonable to expect that they would cross the Atlantic in half the time occupied by the old liners; that New York would be brought within a ten or fourteen days' voyage from London, Bristol, or Liverpool; and that the arrival of advices might be calculated with certainty to a day, if not to an hour. The effects of this, not only on commerce, but on every department of trade and manufactures—not only on the merchant and broker, but on the manufacturer and artisan—it was difficult to over-estimate.

However, amid all this thinking and prophesying, amid the calculations of philosophers and the speculations of merchants, hundreds of workmen were engaged at Bristol in constructing a large steamer, to be called the *Great Western*, which should at once and for ever set the question at rest. The men of practice did not share the doubts of the men of theory; capital was supplied to a sufficient extent, and the public looked on in anxious expectation of the result. The *Great Western* was

finished in 1838, and announced to sail on her first voyage on the 8th of April. The appearance of this magnificent steamer inspired all spectators with confidence in her fitness for the work. Seen from a distance, she had an appearance of strength rather than of beauty; above the long black hull rose a short thick funnel and four masts; the deck, 236 feet long, was not curved like those of many other vessels, but almost straight from stem to stern; her huge paddle-boxes, distant from each other nearly sixty feet, covered wheels twenty-eight feet in diameter, to which were attached paddles ten feet long. The horse-power of the engines was 450; the weight of the boilers and machinery 300 tons. She seemed a strong and compact ship, and not likely to be easily turned aside from her course by either the winds or the waves of the Atlantic. But when the visitor went on board, he was filled with as much admiration of her beauty as of her strength; the cabin accommodation was of the most splendid kind, not excelled by any hotel on shore. Sofas, couches, handsome mahogany tables, and other elegant furniture, adorned the saloons; the decorations were most profuse and elaborate; while large mirrors multiplied all this splendour. The sleeping apartments were so neat, so clean, and so comfortable, that their improvement seemed to be almost impossible. When the elegant and luxurious cabins were left, and a visitor stood before the colossal machinery, wonder seemed to be exhausted, and all doubts of the success of the enterprise fled away.—We are familiar with such things now; but they were real marvels in those days.

The *Great Western* sailed from Bristol on the 8th April 1838, having on board 660 tons of coal and seven adventurous passengers. Three days previously, the *Sirius*, a vessel of much smaller size, built to ply between London and Cork, had steamed from the latter port right in the teeth of a strong westerly wind, and with New York also for her destination. Never was there such a race as this struggle of two steamers, which should first traverse the entire breadth of the wild Atlantic. The very wind seemed to be angry with the ships.

First it blew a strong gale from the west, that raised a heavy sea; but this, that would have retarded sailing-vessels, never caused the two brave steam-pioneers to alter their course. The wind then for some days kept veering round and round, as if to make a last effort to impede what it could not stop; but it was of no avail: the steamers went steadily on. The *Sirius*, that had the start by three days, made little way comparatively during the first week. She carried more weight in proportion than the *Great Western;* but as her coals were consumed, she became more lively, and, in sporting phrase, 'made more running.' Thus, during the first week she was out, her daily run was never more than 136 miles: on the second day it was only 89. The *Great Western*, on the contrary, made ten miles an hour during the second day, and her average daily speed during the entire voyage was 211 miles. At such a speed she would soon overtake the *Sirius*, that had the start by about 400 miles only. But as the little vessel got lighter she went ahead; on the 14th she ran 218 miles, as much as the *Great Western* on the same day; on the 22d she ran only three miles less than the large ship. Still it was a close chase; but at last the *Sirius*, by reason of her long start, was the winner. She reached New York on the morning of the 23d, and the *Great Western* arrived the same afternoon.

The excitement which prevailed in New York respecting these voyages was intense. Previous to the arrival of the steamers crowds had daily collected on the quay, gazing wistfully eastward over the wide Atlantic. Many of the watchers were old enough to remember the first voyage of what the incredulous had called *Fulton's Folly*, little dreaming then what the future of that *Folly* was to be; and as they now described that memorable voyage to their younger brethren, they remembered how the predictions of the wise had been falsified, and spoke in hope rather than in doubt of the success of the steamers from the Old World. And never were hopes better realised than when, on the morning of the 23d April, a streak of smoke, dim and undefined, was descried in the horizon by the watchers on the quay

'Could it be a steamer?'—'Was it *the* steamer?' passed from mouth to mouth. The smoke came nearer; the hull hove up, as it were, out of the ocean, and a steamer was clearly defined advancing rapidly. The intelligence spread; the city poured out its crowds; and cheer upon cheer arose as the *Sirius* steamed into the harbour, and cast in the Hudson that anchor which, only eighteen days before, had been weighed at Cork. Scarcely had the good citizens time to recover from their first surprise, when the *Great Western* appeared. Streaming with flags, and crowded with people, the *Sirius* lay waiting the arrival of her competitor; and as the *Great Western* sailed round her, three hearty cheers were given and responded to. The battery fired a salute of twenty-six guns; and the passengers drank the health of the President of the Great Republic. As the vessel proceeded to the quay, 'boats crowded round us,' says the journal of one of the passengers, 'in countless confusion: flags were flying, guns firing, and bells ringing.'

The *Sirius* was too small for continued Atlantic navigation; she was soon withdrawn to pursue her original route between Cork and London, and was lost some years afterwards on the coast of Ireland. The *Great Western*, however, continued to ply regularly and successfully. From 1838 to 1844, she made thirty-five outward and thirty-five homeward voyages. The average distance steamed each voyage was nearly 3500 miles; the average time occupied in going *to* New York was 15 days 12 hours, and in returning 13 days 9 hours. The average of passengers being, however, barely 80 each voyage, the *Great Western* was removed from this route, and in 1847 became the property of the West India Steam-packet Company. Other changes of fortune befell her afterwards.

Several steam-ships, some larger even than the *Great Western*, navigated the Atlantic between 1838 and 1843; but, with the exception of those employed by the Admiralty to carry the mail, they all, for various reasons, were withdrawn. The *Royal William* was the first in order of time; after making a few passages, she was removed, and placed on another station.

Then followed the *British Queen*, the *President*, and the *Liverpool*—all three of large size, and built at a cost of about £100,000 each. They had made very few voyages across the Atlantic, when the first was sold to the Belgian government; the second was lost in 1841; and the third was placed on the station between Southampton and Alexandria, and was lost some years ago on the Spanish coast. No sooner had the *Great Western* performed her first voyage to New York and back, than the directors of the company which owned her found that steam-ships of larger dimensions would offer better chances of remuneration. They resolved to build a second, but of iron instead of wood, and propelled by the screw instead of the paddle-wheel. Accordingly, the keel of the *Great Britain* was laid at Bristol in 1839, and after some mishaps in building, the vessel was launched in 1843—Prince Albert acting as sponsor on the occasion. The noble ship was in length 322 feet, breadth 51, and depth 32. She could stow away 1200 tons of coal; the weight of the engines was 340, and of the boilers 200 tons. The engines were of 1000 horse-power; they gave motion to a drum 18 feet in diameter, which communicated by means of chains, weighing 7 tons, with another drum one-third of the diameter of the first. The latter drove a shaft 130 feet long, passing immediately above the keel to the screw, which had six arms placed in a circle—each arm about 7 feet long, and shaped somewhat like the bent tail of a salmon. The screw weighed 4 tons, and wrought in a space left immediately in front of the helm. The want of paddle-boxes, and the consequently clean run of the ship, gave her a very handsome appearance; and when seen in the graving-dock at Liverpool from keelson to topmast, the admiration of her beautiful proportions increased as inspection became closer. The saloons and berths were elegantly fitted up, but not so expensively as those of the *Great Western*. Her six masts (afterwards reduced to five) could spread as much canvas (5000 yards) as a fifty-two gun frigate; but as the masts were all low, instead of requiring a frigate's complement of seamen, the comparatively small number of thirty was sufficient

to manage the sails of the *Great Britain*. Even as a sailing-vessel, it was expected that she would go through the water as fast as a frigate, and certainly much faster than any paddle-steamer under sail only; for the screw would not impede the progress of the ship to anything like the extent of paddle-boxes and wheels. Her entire cost was about £100,000. Her sailing and steaming qualities were tested with satisfactory results, and it was considered that she would for many years be the swiftest and safest Atlantic steamer. A few voyages in 1845—1846 seemed to confirm this idea; but her successful career was suddenly stopped. She went ashore on the Irish coast, and remained aground for a whole year. On being floated again, she was sold for a trifle to a Liverpool firm, altered and refitted, and placed on the Australian route, where she has ever since rendered admirable service.

§ V. CUNARD LINE OF ATLANTIC STEAMERS.

In 1838, shortly after the successful voyages of the *Sirius* and *Great Western*, the government advertised for tenders for carrying the mails in steamers between this country and America. Both the companies to which these two vessels belonged made offers. Neither of the tenders was accepted; but shortly afterwards, a proposal was made to the government by Mr (afterwards Sir) Samuel Cunard, of Halifax, in Nova Scotia. He proposed to take the Atlantic contract, and carry the mails once a week. This proposition was not acceded to at the time; but eventually it was arranged that he was to receive £65,000 per annum for seven years for conveying the mails twice each month between Liverpool, Halifax, Quebec, and Boston. This was the commencement of what is now well known as Cunard's line. In 1840, a steamer named the *Britannia*, of 1200 tons burden, 440 horse-

power, and 230 feet in length (the same dimensions nearly as the *Great Western*), arrived in the Mersey to commence the fulfilment of Mr Cunard's contract. She left Liverpool on the 4th July, arriving at Halifax in twelve days ten hours, and performing the voyage homeward from Halifax in ten days. The other vessels placed on this line at the outset were the *Acadia*, *Columbia*, and *Caledonia*. They were all built in the Clyde, and their dimensions were nearly the same as that of the *Britannia*. More powerful vessels were afterwards constructed, and in consideration thereof, the payment was raised to £90,000 per annum, subsequently reduced to £85,000 when the service to Quebec was taken off. The regularity with which the mails were carried was a theme of general admiration. The vessels were looked for and usually arrived on the appointed day; and passengers went on board to cross the Atlantic with almost as little fear as is felt in stepping into a railway carriage. Indeed, the voyages were made with such regularity, that it was no uncommon thing for the captains to tell, on the eve of sailing, when they would be back to dinner, and they usually kept their time. Let the reader imagine a man about to perform a voyage over 6000 miles of ocean, and instead of thinking about making his will or arranging his affairs, coolly specifying the time when, after having crossed to America, he will come back to dine in Europe!

It was not until after all but Cunard's ships had been withdrawn, that American-built steamers began to ply between England and New York. The formation of several companies for this purpose made Mr Cunard anxious, in 1848, to extend his contract, so as to carry the mails once a week, and to render him more able to meet the expected competition. The proposal was agreed to: the mails were to be carried from Liverpool every Saturday, and from Boston or New York every Wednesday (except during four winter months, when it was to be fortnightly), arrangements being made by which the détour to Halifax was to be abandoned. The subsidy was increased, but not in equal ratio to the increase of service

The steam-ships originally possessed by Mr Cunard were now superseded by others of greater size and power, the tonnage being increased from 1200 to more than 2000, and the horse-power of the engines from 440 to 800. Of the old ships, one was lost and the others sold; and the Cunard fleet in 1851 comprised the *Africa*, *Asia*, *America*, *Cambria*, *Canada*, *Europa*, and *Niagara*. The first two of these were 280 feet long, 2266 tons, and 800 horse-power. All these vessels were built in the Clyde. In 1849, the average length of passage from Liverpool to Halifax was 11 days 3 hours; from Halifax to Liverpool, 9 days 21 hours; Halifax to Boston, 34 hours; Halifax to New York, 55 hours; New York to Halifax, 62 hours; and Boston to Halifax, 41 hours. These returns shew a marked increase in speed over the early voyages of steamers across the Atlantic.

To furnish a notion of the general arrangements, beauty, and comforts of the Cunard steamers, we will make an extract from Mr W. Chambers's *Things as they are in America*. When we state (as will appear presently in detail) that the *America*, to which the extract refers, is less than half the burden of some of the steamers now plying on the line, it will give an idea what the latter must be. The mails being brought on board the *America* at Liverpool, the voyage began.

'The captain and pilot took their places on the paddle-box, the other officers went to their appropriate posts, the bell was rung, the wheels moved, and we were off. Slowly at first did the great floating mass proceed through the water. The mists which lay to seaward were not yet quite dispelled by the sun, and to go down the Mersey required careful guidance. For half an hour, the passengers leant over the brass railings of the elevated poop, catching glimpses of the parting quays—some waving hats or handkerchiefs to friends far in the receding distance—some, myself for one, thinking of those dear to them at home, and half doubtful of our own safe return to Old England. Gradually, the ship got into greater speed; for an instant it paused in its career, to allow

the pilot to descend to his boat; again it moved along, and we were fairly on our course. The direction it took was straight up the Channel between Ireland and the Isle of Man. It was going what is called "north about," which is preferred to the southern passage in certain states of wind and tide. As the vessel gained the open sea, and left nothing to look at but the wide-spread waters, one by one the passengers descended to view the nature of their own particular accommodations, or to inspect the general mechanism of the ship.'

Now for the vessel itself. 'On board the *America*, which bears a close resemblance to the other vessels in the line, there was nothing to find fault with, but, on the contrary, much to commend. Everything in the Cunards goes on, as the saying is, "like clock-work." In the striking of bells, changing of watches, posting of officers, throwing the log, taking solar observations, and other transactions, there is all the regularity and precision of a man-of-war; and this imparts a feeling of security even in the worst states of the weather, by night or day. The quantity of fuel consumed is from fifty to sixty tons a day; necessitating a stock on board of about 900 tons of coal for the trip, and so leaving space for 900 tons of goods. It is wonderful to see how much is made of the internal accommodation. A great deal is done on deck. There is really little deck visible. Along each side, adjoining the paddle-box, there is a row of small apartments, covered with wood, and over these are empty boats turned upside down, ready for launching in case of accident. In the open space beneath these boats, the cook keeps his fresh vegetables; and you occasionally see one of his assistants climbing up to clutch at a cabbage or bunch of carrots, and bring them from their repository. The apartments on the starboard side (the right side, looking towards the head of the vessel) have brass plates on the doors, with inscriptions denoting what they are. The first in the row is the cabin of the second officer; next is the cabin of the third officer; next is the workshop of the baker; next is that of the butcher or flesher; next is

the house for the cow; and further on are sundry smaller offices. The apartments on the left side of the deck (larboard) are—first, the cabin of the surgeon; next, that of the purser; and further on are various places for culinary operations, stores, and so forth. Along the centre of the deck, beginning at the stern, are, first, the wheel-house, in which a helmsman is seen constantly at his post, and who has an outlook in front over the top of the saloon. At each side of the wheel-house are apartments for the captain and first officer. The saloon comes next. It is a large sitting and dining apartment for the first-class passengers, and is lighted by a row of windows on each side. Separated from it by a narrow cross-passage, and on the same line with it, is the steward's apartment, surrounded by shelves of china and glass articles, and having in its centre a little bureau whence liquors are dispensed. Over the door of this bureau is a clock, visible from the saloon, which is altered daily in correspondence with the changing longitude. Beyond the steward's room, towards the middle of the vessel, is a kind of apartment open at the sides, and in which stands the capstan. At its extremity, is the enclosed chimney of the furnaces, by which means the enclosure is kept tolerably warm even in cold weather. Provided with seats, it forms the outdoor lounge of cigar-smokers, and those who do not know what to do with themselves. Besides being dry overhead, the capstan gallery is kept dry to the feet by means of open wooden work laid on the deck; so that when the sea washes over the vessel, passengers can remain here without being wetted. Beyond the capstan-gallery is the kitchen; adjoining is the open deck, with the ventilators for the engine-room. Clearing this spot towards the head of the vessel, we have, first, the mess-room of the officers, a small apartment erected on the deck; and in continuation, the sitting and eating saloon for the fore-cabin passengers. All beyond is the proper field for the sailors.'

All this, it will be remembered, is on the deck level. 'With so many incumbrances, the space left for walking amounts

only to a stripe at each side of the saloon, unless we choose to mount to the poop, which is the entire roof of the saloon, steward's apartment, and capstan-gallery, united in one long sweep. Below the saloon are the sleeping-berths, two beds in each, in long rows; a certain number with a small parlour being set aside for ladies. The descent to this sleeping region is by two good stairs. The fore-cabin passengers, in like manner, occupy berths below their saloon, and in this respect at least, enjoy accommodations no way inferior to those of first-class passengers.'

Then for the navigation. 'The conducting of this magnificent vessel from port to port across the ocean, exhibits a remarkable triumph of human skill. A body of officers, dressed in a uniform like that of the royal navy, is charged with the management of the ship. The chief command in the *America*, for the time being, was in the hands of Captain Shannon, a Scotsman of experienced seamanship, and most agreeable and obliging in his intercourse with the passengers. Under him are three officers. The laborious duties of the ship are performed by a boatswain and an efficient corps of mariners; there is likewise a head-engineer with his assistants, having the special charge of the machinery. In the ordinary working of the ship, it seems to be a rule, that two officers shall always be on the alert—one stationed on the gangway at the side of the paddle-boxes, to look sharply ahead; the other stationed at the binnacle, to communicate orders to the man at the wheel. When an order is issued by the captain, or first officer on duty, it is repeated aloud by the second officer; and you thus hear it rapidly echoed from point to point till acted upon by the helmsman. Orders to the engineer to slacken speed, to stop, or go on, are communicated by pulling the wire of a bell at the paddle-box; by which simple contrivance, the movements of the ship are under the most perfect control.' Electric action is now much used in such cases. 'The watches, as must be known to many, are four hours each, and are regulated by striking a bell placed near the wheel, the sounds being answered

by a bell at the forecastle. The bell is struck every half-hour. Half-past twelve o'clock is indicated by one blow; one o'clock by two blows; half-past one o'clock by three blows; and so on to four o'clock, which is marked by eight blows. At half-past four they begin again; and in this way the twenty-four hours of the day are divided. Although ably assisted by his officers, the commander of a vessel of this class holds a situation requiring sleepless vigilance. I observed that in his room at night a light was kept constantly burning, to illuminate the charts, compasses, and barometers with which the apartment is furnished; and at various times a mariner came to report the progress of the ship, and the state of the winds. It is also noticeable, that any order despatched by the captain to the officer on duty, is given in writing, so as to avoid the mistakes incidental to verbal messages. Latterly, a tell-tale compass has been invented, for the purpose of checking irregularities in sailing. By means of an ingenious kind of mechanism attached to a compass, its dial-plate is punctured in the line of direction of the ship. Should the vessel be kept unsteadily on its assigned course, the deviations will be marked on the dial like a cloud of zigzag punctures; but should the vessel be kept steadily to its proper path, the punctures, accordingly, will be in a straight line. Fresh dials of paper are supplied daily. With one of these tell-tale compasses, the captain, on awaking in his berth, can discover whether his orders have been carefully attended to or otherwise.'

The influence of magnetism on ships' compasses is often a matter of great importance. 'Captains of ocean steamers differ considerably in their attention to exactness in compasses. Good compasses are doubtless furnished to all vessels of this important class; but the very best may be rendered worse than useless, by a disregard of the petty circumstances on board that derange its action. Captain Shannon related to us a curious instance of a derangement in the compass, which had since rendered him punctiliously cautious. He had left Halifax with his vessel on the homeward-bound voyage; it was during one of the cold

winter months, when fogs prevail on the American coast. His directions at night to the officers of the watch were to run for a point thirty miles eastward of Newfoundland, so as to make sure of keeping clear of its rock-bound shores; and the point of the compass that would lead in this required direction was fixed upon. On coming on deck in the gray of the morning, what was his horror on seeing that the ship had just entered a small bay, and seemed about to be dashed in pieces on the lofty precipices that revealed themselves through the mist! By instantaneously shouting orders to the man at the wheel, and by reversing the engines, he barely saved the vessel from destruction. After some trouble, it was paddled out to deep water. His first impression of course was, that the compass had been neglected; but, to his surprise, he found that his orders in that respect had been exactly followed. The head of the vessel had been kept in the direction which, by compass, should have led to the open sea, thirty miles from land, and yet here was it running full inshore. To all concerned, the deviation seemed perfectly magical—not on any ordinary principle to be accounted for. The truth at length dawned on the captain. The error must have arisen from some local derangement of the compass. He caused all the compasses in the ship to be ranged on the deck; and soon it was perceived that no two agreed. The seat of the disorder was ascertained to be at a certain spot close to the funnel of the stove of the saloon. Could this funnel be the cause? It was of brass, and had never before shewn any power of distracting the needle. On looking into it, however, the captain discovered that, when at Halifax, a new iron tube had been put inside the brass one, without his knowledge, and the circumstance had never been mentioned to him! There, in that paltry iron tube, was the whole cause of the derangement, "which I speedily," added Captain Shannon, "made it to shift its quarters." How near was thus a fine vessel being wrecked, from a petty circumstance which no one could have previously dreamt of; and it may be said, how many first-class steamers, assumed to be diverted towards rocks

currents, may have been led to destruction from causes equally trivial!'

But, in truth, the captain of such a steamer has to keep his mind awake to all kinds of possible mishaps. Nevertheless, 'by a strict regard to compasses and to lights, and by careful pilotage on approaching the coast, the danger to well-built seagoing steamers is exceedingly small. Rocks, collisions, and conflagrations are the things that need alone raise a feeling of apprehension. On board the *America*, as in similar vessels, lights are hung up at sunset on the fore-mast and on each paddle-box, so as to warn ships that a steamer is approaching, whereby collisions may be avoided; and as regards fire, extreme care seems to be taken. All the lamps below, excepting that in the captain's apartment, are put out at midnight; nor is any one allowed to burn lights on his own account. There is also, in connection with the steam-engine, a set of force-pumps, by which a deluge of water could be immediately propelled to any part of the vessel. To avert the danger and delay incidental to breakages of machinery, duplicates of various parts are kept on board, and could be substituted if necessary, without materially interrupting the progress of the voyage. Such precautionary arrangements cannot but give a certain degree of confidence to the most timid class of passengers.'

Concerning the arrangements for passengers' meals, 'one of the first things which passengers do on coming on board, is to select the place where they propose to sit at table, which they do by laying down their card at the spot. In this way, a party of persons acquainted with each other make choice of a locality, and the seat each selects he keeps during the voyage. It is one of the many well-managed matters in these vessels, that the meals are served peremptorily to a minute, according to the striking of the bells. No matter what be the state of the weather, the dishes are brought in at the appointed time; and I verily believe that if the ship were sinking, the stewards would still be continuing to serve the dinner. The stewards, in fact, twelve in number, the whole under a *chef*, and dressed in smart

blue jackets, are but a variety of the waiter genus, and know only one thing—which is, to supply the wants of passengers. At eight o'clock in the morning they ring their first bell, which is the signal for rising; and at half-past eight they ring again for breakfast. Irish stew, cold meat, ham, mutton-chops, some kind of fish, eggs, tea, coffee, and hot rolls are placed in profusion on the two upper tables. The tables in the saloon are eight in number—that is, four on each side, with sofa seats in red velvet plush. Seldom more, however, than the upper tables are covered for breakfast; for the meal is drawn out till ten o'clock, and for two hours people come dropping in and going out as suits their fancy. At ten, the tables are cleared; after this nothing hot can be obtained, but any one at any time can have such other fare as is on board. At half-past eleven, the tables are covered to a larger extent, and the bell at twelve o'clock is the signal for lunch. This is a well-attended meal, and there is usually a considerable consumption of soup, cold beef, and roasted potatoes—the latter served with their jackets on, and a great favourite with the more moderate hands. Again the tables are cleared, and so they remain till half-past three o'clock, when they are covered from end to end in *grande tenue*, and the bell for dressing is rung. This bell might as well be spared, for not one makes the slightest preparation; and when the bell at four o'clock is sounded, there is a general rush from the poop, smoking-gallery, and other quarters, into the saloon. The number of passengers during our voyage was a hundred and sixty, and the whole of these, with two or three exceptions, sat down to dinner daily. At the top of each of the eight tables is a silver tureen of soup, and the signal for taking off the lids is the entrance of the captain, who appears in the saloon only at this meal, and takes his seat at the upper end of the first table on the left-hand side. The stewards are drawn up in lines, and confine their attendance to their respective tables. When dishes are sent in to the apartment, they are handed from one to another along the lines, and in the same noiseless manner are they handed out—the whole thing going on silently like a

adroit military manœuvre. Every day fresh bills of fare are laid on the tables for the use of the guests. Iced water is served in abundance, and it is observable that not many call for wines. Those who do, give their orders on cards furnished for the purpose, which they settle for at the end of the voyage.'

The dietary, it will be seen, is most liberal. 'The elegance and profusion of these dinners is surprising. They consist of the best soups, fish, meat, fowls, and game, with side-dishes in the French style; followed by a course of pastry of various kinds, with a dessert of fresh and preserved fruits. How so many things can be cooked, how there can be so much pastry dressed up daily, is a standing wonder to everybody. And the wonder is greater when we know that from the same apparatus must be daily produced not only all this profusion for the saloon, but also copious dinners at different hours for the fore-cabin passengers, the officers' mess, and the working departments of the ship. Dinner in the saloon is drawn out to upwards of an hour, but towards its conclusion numbers drop off to their accustomed lounge in the capstan-gallery or on the poop. A few, here and there, linger over a bottle of wine; some recline on the sofas; and some take to reading. There is now a cessation in eating till seven o'clock, when the bell is sounded the last time for the day, and tea and coffee are served. For these beverages there is always abundance of milk; the cow on board being an assurance that there will be no want in that particular. . . . . It will appear, from this brief description, that eating goes on with short interruptions from morning till night. One feels as if living in a table-d'hôte room, with the same company always sitting down and rising up; and I should think that, if a person be at all well, he can scarcely fail to add to his weight during the voyage.'

But how do the passengers spend their spare hours? 'In tolerable states of the weather, the greater number of passengers take walking exercise on the poop, which is the great airing-ground. The younger men amuse themselves in a different manner, with games of shovel-board, on the stripes of deck

outside the saloon. Here, with thin circular pieces of hard-wood, they play at a game which resembles that of bowls, only that the pieces thrown are made to slide along instead of being rolled. On fine forenoons, the ladies are spectators of these games, or indulge in walking exercise, if able to bear the unsteady motion of the ship. In the saloon, much is done to kill time by card-playing, chess, and backgammon. Some keep playing on for hours, morning and evening. They have crossed the Atlantic a dozen times, and to them the whole affair is hackneyed and tame. Their only solace is whist; and accordingly no sooner is the breakfast off the table, than the cards make their appearance. At night, when the candles are lighted, these whist-parties increase in number, and to look down the room, you would imagine yourself at a large evening party in a watering-place. Occasionally, towards ten o'clock, when certain youngsters are finishing the day with deviled legs of fowl and "glasses of something warm to put away that nasty squeamishness," you may hear a song break forth, and there is for a time an air of jovialty among the various scattered parties. Yet on no occasion does one ever see any approach to boisterousness; and notwithstanding the mixture of nations—English, Scotch, American, Canadian, German, and Italian—there prevails from first to last the staid demeanour of well-bred and select society.'

On some rough rainy days, 'the beating of rain and wind, and the dashing of spray from the paddles, were the least of the discomforts. As the vessel ducked down in front to meet the billows, she constantly, and just as a spoon would lift water, shipped a sea, which came rolling along the decks ankle-deep, and finding only an imperfect outlet at the scuppers. The concussions of the heavy surging waves on the bows and paddles were sometimes awful, threatening, as they appeared to do, the destruction of everything that opposed the repeated shocks. Yet under these pitiless blows, the vessel scarcely quivered, so well were her timbers put together; and calmly she made her way, though at moderated speed, through the raging and foaming

ocean. Now was it apparent that mere power of engine is of little avail during storms in the Atlantic, and, indeed, will only aggravate the concussions, unless the prow of the vessel be of that sharpened and vertical form that will enable it to cleave its way, and at the same time sustain a level course in the water. . . . . It was remarkable, that during even the worst weather, and when the motion of the vessel was considerable, there was little sickness among the passengers. Altogether, I experienced no feeling of this kind except for an hour on the second day. The length and solidity of the vessel, with its power of overcoming the short broken waves, give an easiness that is wanting in the small class of steamers; so that a voyage to America is really attended with less painful consequences than an ordinary trip from Dover to Calais. While the bad weather lasted, only two of the passengers ventured on the poop.'

Captain Basil Hall once gave a graphic account of Sunday on board a man-of-war; let us see what it is like in a Cunard steamer. 'On the eighth day out, the weather mended very considerably, and at noon our run by log was 231 miles. Being Sunday, preparations were made for performing divine service. At one o'clock, the principal steward entered the saloon with a tray-full of Bibles and prayer-books, which he distributed among the passengers. He then adjusted a red plush sofa-cushion on the inner side of one of the tables, by way of pulpit; and after these simple arrangements, the bell on the forecastle began deliberately to toll. Several passengers from the fore-cabin now entered along with the officers in uniform, and about a dozen sailors in their Sunday jackets. In the whole scene there was an air of considerable solemnity. The bell ceased to ring, and a perfect silence prevailed. The officiating minister now took his seat at the cushion, on which lay a large Bible and service-book. When no clergyman is on board, the service for the day is read by the captain. In the present instance, a clergyman belonging to the college of Toronto was a passenger, and by him the service was conducted according to the usual forms; including the preaching of a sermon, which was listened to with

as great attention as if delivered in a parish church. The rest of the day was spent with the ordinary decorum of Sunday in England.'

Then the 'beginning of the end' gradually appears. 'On the following Tuesday, being the tenth day out, sailing vessels began to be seen on the horizon, being probably barks engaged in the fishing on the banks of Newfoundland, which we were now declared to be upon. We also enjoyed an agreeable clearing up in the sky, and the colour of the sea changed from blue to a light greenish tinge. From this time, too, more gulls were seen on the wing; and the ship had become a refuge for a flight of small birds resembling larks, which had been driven from land by stress of weather, and were glad to rest their wearied wings by perching on the more prominent parts of the vessel. This day, about noon, a large steamer from New York to Liverpool came in sight, and was watched with deep interest by the passengers. It passed at the distance of two miles. There were, as usual, mutual greetings by signal. The system of communication at sea, by signals, is one of the most remarkable inventions of the day, and merits a word of explanation. By Marryat's signals, as they are generally termed, a conversation on almost any subject can be carried on between two ships as effectually as if the respective captains spoke to each other in distinct words. The signals employed consist of fifteen different small narrow flags, which are run up at a point over the stern, and fully visible through a glass at a distance of several miles. Ten of them represent the ten figures in arithmetic, and by these any number is expressed. The other five refer respectively to certain departments in the code, and are designed to lead at once to the subject of conversation. When a particular number is expressed, the code, which is a volume resembling a dictionary, is turned up by the party addressed, and he sees a sentence or part of a sentence opposite that number in the book. So expert, however, do mariners become in reading the signals, that they seldom require to refer to the code. On both sides, the signals are run up and pulled down, and questions asked and answered

with the rapidity of ordinary conversation. In this way, vessels passing within sight of each other at sea, no longer need to bend from their course or stop in their career to put questions through speaking-trumpets. The merchant-ships of nearly all countries,' and our own Royal Navy, 'have embraced Marryat's code, which is now therefore the universal language of the sea—a symbol of brotherhood among nations.'

And then the end itself. 'Thursday, the twelfth day out. The joyful intelligence of land being in sight, was reported at breakfast. Through the misty distance, rugged headlands and brown rocky hills were visible on the west. We were now going southward, down the American coast, which was kept in view all day. The prospect was not cheering, for the land facing the ocean about the Gulf of St Lawrence has a generally bare and deserted appearance.' The discussion of various themes by the 'capstan parliament, as we named it, came abruptly to a close in the evening, when the lights at the mouth of Halifax harbour shone in sight. Swiftly the entrance is made; the lights of the town make their appearance; mails and baggage are brought on deck; guns are fired and rockets sent up; lanterns flit about the wooden quay where we are to land; ropes are thrown out; a gangway is pushed on board; and, along with some half-dozen fellow-passengers who go no further, I scramble ashore, and have my foot on American soil. The voyage, so far, had occupied nearly twelve and a half days; which, with a delay of several hours for coaling and the subsequent run to Boston, would, to the bulk of the passengers, make a voyage of fourteen days.'

We now take up the later proceedings of the Cunard Company. After the renewal and enlargement of the contract with the British government, the company strengthened their fleet with the *America*, *Niagara*, *Canada*, and *Europa* in 1840, and the *Asia* and *Africa* in 1850. In 1856, a magnificent addition was made in the *Persia*, a noble ship of 3600 tons and 900 horse-power. Some years later, in 1862, a still finer ship, the *Scotia*, was put upon the line, of 3870 tons and 1000 horse-

power. Five new ships were added in 1864, and six others were in progress in 1865. The old and smaller steamers have been, one by one, sold to make way for better. We may enumerate thirty-eight steamers on the active list, in the summer of 1866, as follow:

	Tons.	Horse-power.		Tons.	Horse-power.
Scotia	3870	1000	Marathon	1784	250
Persia	3600	900	Kedar	1783	250
Australasian	2760	700	Morocco	1783	250
Java	2700	600	Sidon	1782	250
Cuba	2700	600	Palestine	1377	260
China	2527	550	Corsica	1134	200
Asia	2227	750	Baalbec	834	150
Africa	2226	750	British Queen	763	150
Tripoli	2061	280	Stromboli	734	120
Aleppo	2061	280	Penguin	680	180
Tarifa	2061	280	Wolf	670	288
Palmyra	2061	280	Buffalo	670	280
Europa	1981	700	Llama	670	280
Canada	1831	650	Ostrich	624	150
America	1826	650	Roe	559	265
Niagara	1825	650	Lynx	499	[illegible]
Olympus	1794	250	Beagle	454	[illegible]
Atlas	1794	250	Jackal	180	100
Hecla	1785	250	Satellite	154	[illegible]

The smaller vessels do not cross the ocean; they are employed in various subsidiary services. The earlier ships of the company were of wood; those now running are mostly of iron. The paddle is more used than the screw. The *Scotia* is the fastest as well as largest, she having once made the run from New York to Liverpool within nine days, allowing for difference of clock-time; the *Persia* and *China* have nearly equalled this wonderful run. The magnificent *Scotia*, which can accommodate no less than 300 saloon passengers, is 366 feet length of keel, 48 breadth of beam, 33 depth of hold. Although her registered tonnage is put down at 3870 tons, she counts 4050 tons builders' measurement, and displaces 5620 tons of water; her cylinders

are 100 inches diameter, and 12-feet stroke; her boilers present 24,000 square feet of heating surface; her interior is divided into seven water-tight compartments by six iron partitions, besides four water-tight caissons or subsidiary compartments. Whether or not she is 'the strongest as well as the finest merchant-ship afloat,' she certainly deserves the character which Mr Willox, in his useful account of the Liverpool steam-marine, gives her, of being 'the pride of the Mersey.'

§ VI. OTHER STEAM-ROUTES TO NORTH AMERICA.

THE Cunard Company never have had a monopoly of the steam-trade from Europe to North America. The 'Collins' Company, a competitor on the same route, arose out of previous achievements in ocean-steaming by the Americans. The American steamers that first plied regularly on the Atlantic route were the *Washington* and *Hermann*, of about 2000 tons burden. They, however, did not depend entirely on the British traffic, but made the port of Bremen their terminus in Europe, calling at Southampton on their way.

The line of vessels that entered into direct competition with Cunard's was projected by Mr Collins of New York, and consisted of five steamers of 3000 tons burden, 300 feet long, and propelled by engines of 1000 horse-power. They were named the *Atlantic*, *Pacific*, *Arctic*, *Baltic*, and *Adriatic*. They were longer and more powerful than any steamer built up to that time, except the *Great Britain*. The merits of the rival lines soon became a national question, and the citizens of the great republic spoke confidently of the superior speed their vessels would attain. The feat which these American ships were expected to perform was of no ordinary difficulty. For ten years Cunard's line had navigated the Atlantic with a regularity and speed which it would be exceedingly difficult even to

equal. The first ship of the Collins line, the *Atlantic*, sailed from New York on the 27th April 1850. As the time of her arrival at Liverpool drew near, the interest felt by the people of that town in the voyage became intense. When she arrived, it was found that no entrance to the Liverpool docks was sufficiently wide to admit the *Atlantic*, and she and her consorts had to lie in the river until a new dock that had been preparing for them, with entrance-gates eighty feet wide, was finished. When all the Collins ships were ready, there commenced that rivalry which made a gigantic race-course of the Atlantic Ocean—a race-course so long, that the difference in the longitude of its termini makes a difference of nearly five hours in the time of day; and thus, while people at the American end are rising from their beds, those at the European have got through much of their day's work. The prizes of the turf are paltry compared with that for which those steamers contended—the proud distinction of establishing the most speedy and safe communication between two great continents and two mighty nations.

The superiority was not distinctly declared on either side. The swiftest outward passage in 1850 was that of the *Pacific* in September, when only 10 days 5 hours were occupied between Liverpool and New York; and the swiftest homeward that of the *Asia*, in 10½ days between New York and Liverpool. The Collins line proved eventually to be a disastrous failure. The contract with the United States government was, first, for twenty voyages a year, at a subsidy for each voyage; then for twenty-six voyages a year, at an increased subsidy. But all would not do. The expenses of construction and working were so enormous, and the loss of two of the ships by wreck so disheartening, that the whole enterprise was abandoned, and the Collins Company broken up.

But although this company failed, others have succeeded in establishing magnificent and successful lines of steamers between Europe and North America, partially but not wholly competing with the Cunard line. One of these is the 'Inman' line, or, to give it its full name, the 'Liverpool, New York, and Philadelphia

Steam-ship Company.' This line has been honourably distinguished for its development of the screw-propeller principle. In 1840, Liverpool was visited by the first screw-steamer, the *Propeller;* and the ship-owners, perceiving the capabilities of the principle, gradually adopted it for coasting steamers. In 1850 Messrs Todd and Macgregor built the second ocean-going iron screw-steamer (the *Great Britain* having been the first), called the *City of Glasgow.* It plied several times across the Atlantic, and then passed into the hands of a Liverpool company, becoming the precursor of the present fine fleet of the Inman line. This company obtained the mail contract from the United States government after the break-down of the Collins line, and have ever since conducted a great mail, passenger, and merchandise trade. The steamers ply twice a week between Liverpool and New York, every Wednesday and Saturday in each direction. They are sixteen or eighteen in number, mostly named after cities, such as the *City of Boston,* &c.; all are iron screw-steamers, generally of about 2000 tons, and many of them have steel plates to strengthen the hull and decks.

Another is the 'Montreal Ocean Steam Company.' In 1852, the Canadian government invited tenders for steam-ships to ply between Liverpool and Canada: a beginning was made, but various circumstances delayed the completion of the scheme until 1856, when a company entered vigorously on the work. Steamers now run once a week from Liverpool to Quebec during the summer, and to Portland during the winter. One of them, the *Peruvian,* is as much as 2500 tons register, a strongly built and beautifully finished iron screw-steamer.

The 'National Steam-ship Company,' another Liverpool body, possess several very large steamers—the *Queen, Louisiana, Virginia, Pennsylvania, Erin,* and *Helvetia,* of which two are 2887 tons each, and two 3318 tons. Others are being added of 3600 tons. The *Queen,* a recently built member of the fleet, is a noble ship 370 feet long, with a carrying capacity of nearly 4000 tons, iron masts, and steel yards.

France, too, has been alive to the importance of steam

communication with North America. In 1860, the French government ordered steamers to be built at Glasgow, after French models, but equal in equipment and speed to the famous *Scotia* and *Persia*. There are five of them, large and magnificent, though admittedly not equal to the two just named; they ply between Havre and New York, carrying mails, passengers, and merchandise, and are of great importance to France.

Germany has not been behind-hand with France in this matter. The 'North German Lloyds' is a service of steam-ships between Bremen and New York, calling at Southampton. The *America*, *Bremen*, *Hansa*, *Hermann*, *New York*, *Deutschland* and *Union* are all large and fine steamers, plying once a fortnight in each direction. Another line is that of the 'Hamburg American Packet Company,' going to and fro between Hamburg and New York, calling on the way at Southampton, once a fortnight in each direction. The ships of this line, *Saxonia*, *Bavaria*, *Borussia*, *Teutonia*, *Germania*, and *Allemania* are all large Clyde-built steamers.

There is one failure to record, as disastrous as that of the Collins Company—viz., the 'Atlantic Mail Steam Company.' This was established rather to benefit Ireland, than because there was the enterprise in Ireland suitable for it; and political favouritism had something to do with the matter. The port of departure was Galway, on the west coast of Ireland. A succession of mishaps, accusations, and recriminations brought the speculation to ruin, after only a few voyages had been made across the Atlantic.

§ VII. OCEAN STEAMING ROUND THE CAPE.

VERY little need be said concerning the schemes for sending steamers round the Cape of Good Hope to India, China, and Australia. In 1850 the government advertised for tenders

conveying the mails between England and the Cape of Good Hope, calling at Madeira, Sierra Leone, and St Helena. The vessels were to be of not less than 200 horse-power each, propelled by the screw, and to perform the voyage at a speed of not less than eight knots an hour. This contract was obtained by the General Screw Steam-navigation Company, who undertook to perform the voyage at the rate of 223 miles per day: the distance to be steamed being about 6700 miles, the time occupied would be about a month. The first vessel, the *Bosphorus*, left Plymouth on the 18th December 1850. On arriving at Madeira, the captain sent home extracts from the log, from which it appeared that in six days she ran 1164 miles; on one day she ran 215 miles before a fresh north-east wind without using any steam whatever.

Whether the far east could easily be reached by steam is and has long been a favourite problem. As far back as 1849 there was a scheme for sending steamers round the Cape of Good Hope, across the Indian Ocean to Western Australia, and so on to Adelaide, Melbourne, and Sydney, accommodating the Cape de Verde Islands and St Helena on the way. It is calculated that the distance from Southampton to Sydney would be 13,900 miles round the Cape; 13,300 by Suez, Singapore, and the north-east coast of Australia; about 11,900 if the south-west coast of Australia be taken; and 11,700 *viâ* Panama, Tahiti, and New Zealand. The Panama route would present only two stoppages in a distance of 8000 miles across the Pacific; the Cape route would have 6000 miles of steaming across the Indian Ocean; while the Suez route would be about 5000 miles from Singapore to Sydney. The advantage of the Cape route would be, no transhipment at any isthmus. An 'Australian Steam Navigation Company' was formed, under contract with the government to carry the mails to Australia. Steamers were built, and many voyages made; but the whole affair eventually broke down, and the mails were transferred to the Isthmus of Suez route.

At present, the steam-trade round the Cape to Australia, and

in a partial degree to India and China, is in the hands of commercial companies who bring steam to aid the sail, on the *auxiliary* principle, as it is called. Three noble ships of this class are the *Great Britain*, *Royal Victoria*, and *Royal Standard*, all belonging to Liverpool. They are fully rigged iron sailing-ships, provided with screws as an assistance, but not necessarily dependent on steam-power.

The mail lines and trading lines to the various ports on the African coast itself are of comparatively small amount. How the mails now reach the east, we shall see presently.

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§ VIII. OVERLAND ROUTE TO THE EAST.

We come now to that region of ocean steaming which is in many respects the most important and interesting of all, linking, as it does, the nations of Western and Southern Europe with the rich and fertile east.

On 16th August 1825, the steamer *Enterprise* left Falmouth for Calcutta. She arrived at the Cape 13th October, and at Calcutta 9th December, having been nearly four months on the voyage—or about the same time as a sailing-vessel. It was easy to point out shorter routes to Calcutta, but impossible to find one which could be traversed from end to end by a steamer. By sailing up the Mediterranean a steamer could arrive within a few miles of a sea that formed an unbroken water route to India; but these few miles consisted of the Isthmus of Suez. The only feasible plan was to have two lines of steamers—one in the Mediterranean, the other in the Indian seas—and make the land transit at the most convenient point. But where was that point to be? The most direct way seemed to be across Asia Minor to the Euphrates, down that river to

the Persian Gulf, and so on to Bombay; thus as it were taking one side of a triangle, while the route down the Red Sea traversed the other two. From the coast of the Gulf of Scanderoon to Bir, on the Euphrates, the distance is only about a hundred miles; and though Bir is more than a thousand miles from the mouth of the Euphrates, yet it was considered that all that length of river could be navigated by steamers. But one of the objections urged was, that although a steamer could go easily *down*, it could not get *up*; for at Bir the river is 628 feet above the level of the sea. Other obstacles, and the failure of an expedition fitted out for the purpose about 1836, caused this direct line to be abandoned. The other route was by Alexandria, Cairo, and Suez, which would include a land transit of only 84 miles. This plan was adopted; the British government undertook the route between England and Egypt, and the East India Company that between Egypt and India. In 1837 the arrangement came into operation; the mails were sent from Falmouth to Gibraltar in vessels engaged in the postal service with Portugal and Spain; at Gibraltar they were transferred to Admiralty steamers, which conveyed them to Malta and Alexandria; they were then taken up the Nile to Cairo, and from thence across the desert to Suez, where a steamer belonging to the East India Company was in waiting to convey them to Bombay. The time occupied on this route was between fifty and sixty days, so that the communication with India was reduced by one-half. In order to reduce this time still more, a treaty was made in 1839 with the French government for conveying a portion of the mails through France to Marseilles, from whence they were forwarded to Malta, where they met the steamer from Gibraltar.

Two years before this time, the 'Peninsular Steam Company' entered into a contract with the government for carrying the mails weekly from Falmouth to Gibraltar, calling at Vigo, Oporto, Lisbon, and Cadiz. The advantages were soon apparent, for these steamers brought in five days the mails that had previously sometimes been three weeks on the voyage. In

1839, the government, anxious still further to accelerate the Indian mail, requested the company to submit a plan for the attainment of that object. This was done: the company proposed to establish a line of powerful steamers to run from England to Alexandria, calling only at Gibraltar and Malta; thus rendering the communication by Gibraltar nearly as speedy as that through France. The company procured two large steamers, the *Oriental* and the *Great Liverpool*, and with them and two smaller vessels the contract was begun in 1840.

The postal communication with India having thus been made speedy and regular, a wish was naturally expressed, that on the other side of the isthmus the communication should be extended so as to embrace, not Bombay alone, but also Calcutta, Madras, Ceylon, and China. A contract was entered into with the Company—from that time known as the 'Peninsular and Oriental' or, more briefly, as the 'P. and O. Company'—by which they undertook to convey the mails from Suez to Ceylon, Madras, Calcutta, Penang, Singapore, and Hong Kong. This service was commenced in 1845 with three fine steamers, the *Bentinck*, *Hindostan*, and *Precursor*, of about 2000 tons burden and 500 horse-power. Thus, in less than ten years from its first establishment, this company was navigating the Mediterranean, the Red Sea, and the Indian Ocean, connecting the European shore of the Atlantic with the Asiatic shore of the Pacific, and conducting a constant communication between England and China. Ocean steaming so far developed its power in the next five years, that in 1850 the steamer *Pekin* delivered mails at Hong Kong containing letters which only fifty-five days before had been written at New York; these letters, after crossing the Atlantic, had passed through Liverpool, London, Paris, Marseilles, Malta, Alexandria, and Cairo to Suez, where they were placed on board the *Oriental*, which conveyed them down the Red Sea and across the Indian Ocean to Ceylon, where they were transferred to the *Pekin*, and by her conveyed, after calling at Penang and Singapore, to their final destination.

The distance travelled by these letters was more than half the circumference of the globe.

The fleet possessed by the company in 1851 consisted of 25 steamers, named the *Erin*, *Euxine*, *Ganges*, *Iberia*, *Jupiter*, *Madrid*, *Montrose*, *Pasha*, *Singapore*, *Sultan*, *Tagus*, *Hindostan*, *Indus*, *Ripon*, *Bentinck*, *Haddington*, *Oriental*, *Precursor*, *Achilles*, *Braganza*, *Lady Mary Wood*, *Malta*, *Pekin*, *Pottinger*, and *Canton*. Let us see how the intricate trade was organised by this spirited company. The vessels engaged in the Peninsular service left Southampton three times each month. The first port touched at, after steaming 663 miles, was Vigo, in Spain; from thence the vessel proceeded to Oporto, 68 miles further; and thence to Lisbon, Cadiz, and Gibraltar; arriving at the latter port in eight days after leaving Southampton, and after having steamed 1224 miles. The vessel returned on the same day. Another set of vessels left Southampton on the 29th of each month, arriving at Gibraltar on the 6th of the month following; from thence they proceeded to Malta, Smyrna, and Constantinople, where other vessels were in readiness to extend the communication along the shore of the Black Sea to Trebizond. Some of the vessels also sailed occasionally between Southampton and Naples, calling at Gibraltar, Genoa, Leghorn, and Civita Vecchia. The steamers for Alexandria sailed on the 20th of each month, arriving at Gibraltar on the 26th, at Malta on the 1st of the following month, and at Alexandria on the 9th. At Suez two steamers were in waiting for the passengers and mails conveyed from Alexandria in small steamers up the Nile, and in vans across the desert (the railway was not made at that time). One of the steamers at Suez belonged to the East India Company, and had Bombay for its destination; the other was the property of the Oriental Company. The 10th of the month was fixed as the day of departure; and all persons and things having been shipped, the vessels steamed down the Red Sea to Aden. Here they parted company: the Oriental steamer pursued a course almost due east, across the Indian Ocean to Point de Galle in the island of Ceylon. Having exchanged

mails with the vessel for China, she steamed up the Coromandel coast to Madras, and on to Calcutta, where she arrived in about twenty-eight days from Suez. The vessel in waiting at Point de Galle, as soon as she received what the other had brought, started eastward, and arrived at Penang, in the peninsula of Malacca. From thence, steaming down between Sumatra and the mainland, she arrived at Singapore, almost under the equator, and then up the Chinese Sea, terrible for its typhoons, to Hong Kong, where a small branch-steamer was ready to continue the line of communication to Canton. The number of miles steamed per annum by the vessels of the company in these various services was 381,960.

The changes made in the Overland arrangements between 1851 and 1866, have been influenced by many important circumstances. The lowering of letter-postage and the establishment of book-post; the assumption of the powers of the East India Company by the imperial government; the growth of an enormous trade with the free ports of China and Japan; the great increase of import and export trade consequent on the discovery of gold in Australia; the large emigration of capitalists as well as of labourers to that new world; the frequent tenders to the government from other companies desirous of establishing a healthy competition; the shortening of the transit over the isthmus by the construction of a railway from Alexandria to Suez—all impelled the Peninsular and Oriental Company to introduce larger steamers, increase the speed, and improve the service in various ways.

Australia is now included within the company's programme, as the result of a very complicated and long-continued negotiation. The Peninsular and Oriental Company have at present the Overland route to the east almost entirely in their own hands.

The noble fleet belonging to this company in the summer of 1866 comprised the following ships:

	Tons.	Horse-power.		Tons.	Horse-power.
Mongolia	2799	500	Behar	1603	300
Surat	2596	500	Ellora	1573	300
Simla	2440	630	Emeu	1538	300
Mooltan	2257	400	Geelong	1504	250
Bengal	2185	465	Benares	1491	400
Poonah	2152	500	Salsette	1491	400
Nubia	2095	450	Northam	1330	400
Ceylon	2020	450	Avoca	1284	250
Nemesis	2018	600	Ottawa	1274	200
Pera	2014	450	Ganges*	1190	470
China	2010	400	Singapore*	1190	470
Nyanza	1988	450	Bombay	1186	275
Candia	1982	450	Madras	1185	275
Tanjore	1971	400	Pekin*	1182	400
Malta	1942	500	Euxine*	1165	400
Syria*	1932	450	Sultan	1124	210
Golconda	1909	400	Norna	969	230
Ripon*	1908	450	Cadiz	816	220
Delhi	1898	400	Aden	812	210
Baroda	1873	400	Nepaul	796	200
Carnatic	1776	400	Niphon	790	140
Rangoon	1776	400	Azof	700	180
Orissa	1646	300	Formosa	675	155
Massilia*	1640	400	Granada	561	160
Delta*	1618	400			

The steamers marked * are paddle, all the others are screw; they do not comprise any equal in size to the largest of the Atlantic steamers. The organisation of the mails, leaving Southampton four times a month, in such way as to accommodate the various Oriental regions, and unite all into one general chain, is a marvel of exactness, despite the fact that some of them fail in punctuality occasionally.

Estimates of distances at sea vary according as the mileage is measured on a chart, or as taken on the average of actual voyages, under all the circumstances of wind, tide, and current; but it may be useful to give the company's own table.

	Miles.		Miles.
Southampton to Gibraltar	1151	Madras to Calcutta	779
Gibraltar to Malta	781	Ceylon to Penang	121[illegible]
Malta to Alexandria	819	Penang to Singapore	381
Alexandria to Suez (rail)	252	Singapore to Hong Kong	143[illegible]
Suez to Aden	1308	Hong Kong to Shanghae	8[illegible]
Aden to Mauritius	2336	Shanghae to Nagasaki	4[illegible]
Aden to Bombay	1664	Shanghae to Yokohama	10[illegible]
Aden to Ceylon	2134	Ceylon to K. George's Sound	33[illegible]
Bombay to Ceylon	911	K. G. Sound to Melbourne	13[illegible]
Ceylon to Madras	545	Melbourne to Sydney	5[illegible]

The totals come out thus: Southampton to Bombay, 61[illegible] miles; to Calcutta, 7960; to Hong Kong, 9676; to Japa[illegible] 11,516; to Sydney, 11,875. The overland passage throu[illegible] France saves 1450 miles of sea, at the expense of 740 miles [illegible] railway.

By a new contract, signed early in 1866, the Peninsular a[illegible] Oriental Company bind themselves to convey the mails betwe[illegible] Southampton and Alexandria in 310 hours; Marseilles a[illegible] Alexandria, 155; Suez and Calcutta, 499; Bombay and Hon[illegible] Kong, 413; Hong Kong and Shanghae, 84; and Suez an[illegible] Bombay, 312 hours. They are to be allowed a few hours' grac[illegible] but anything beyond 24 hours involves a forfeit of £50 p[illegible] day; on the other hand, they receive £25 per day for expedit[illegible] or anticipating the delivery of the mails.

There is some probability that when the Mont Ce[illegible] Railway is finished, and unbroken railway communication est[illegible] lished throughout France and Italy, the mails for the E[illegible] will be conveyed overland to Brindisi or some other p[illegible] in the Adriatic, and thence conveyed by steamers to Alexan[illegible] —a quicker route than *viâ* Marseilles and Malta. Capt[illegible] Galton reported on this subject somewhat fully to the gove[illegible] ment in the summer of 1866.

The young and vigorous colony of Queensland in Austr[illegible] has done a bold thing. Beginning with 1866, she has s[illegible] sidised a monthly mail from Brisbane, and other Queensl[illegible] ports, to go through Torres Straits to Batavia, where her m[illegible]

are transferred to Dutch mail steamers going to Singapore; whence they proceed to England.

Were it within the scope of this small volume to notice all the enterprises relating to ocean steam transit, we should have much to say concerning the wonderful trade maintained between Liverpool and the Mediterranean, carried on by several distinct fleets of ocean steamers, owned by wealthy firms and companies, and comprising vessels as large as 2500 tons burden. Almost every nook and corner in the Mediterranean is penetrated by these steamers.

§ IX. WEST INDIA MAIL STEAMERS.

THE necessary result of the successful voyages of the Atlantic and India steamers, was the establishment of other lines of steam communication with countries beyond the sea. The value of our possessions in the West Indies, and the importance of our trade with the rich countries of South America, indicated very clearly the direction of another Atlantic route. The postal communication with these countries was in those days very defective. Even the best sailing-vessels, in the most favourable weather, were four weeks on the voyage; and though the mails were despatched twice each month from England, yet the communication between the various islands and the American continent was neither regular nor certain. In 1840, a contract was made between the Admiralty and the Royal Mail Steam-packet Company, in which the latter agreed, for the sum of £240,000 per annum, 'to provide, maintain, and keep sea-worthy, and in complete repair and readiness, for the purpose of conveying all Her Majesty's mails, a sufficient number (not less than fourteen) of good, substantial, and efficient steam-vessels, of such construction and strength as to be fit and able to carry guns of the largest calibre now used on board of Her Majesty's

steam-vessels of war, each of such vessels to be always supplied with first-rate appropriate steam-engines of not less than 400 collective horse-power; and also a sufficient number (not less than four) of good, substantial, and efficient sailing-vessels, of at least 100 tons burden each.' The steamers were to sail twice every month to Barbadoes; and from thence the mails were to be distributed to the other islands and the continent. The original plan of the voyages of these vessels was described by one of its most earnest and sanguine promoters as a scheme 'which united the British colonies in North America with the British colonies within the northern tropic; which made Barbadoes the highway from all Eastern South America to Europe and to North America; which made Jamaica the great road from all Western America and New South Wales to Britain; which made Nassau the central point to catch everything from and to the Gulf of Mexico; and which connected all the western world in one unbroken line of rapid and regular commercial communication.' The total number of miles to be annually steamed was 684,816; and the contract was to be for ten years, to commence in 1841. The company had thus less than two years to make preparations for an enterprise that was truly gigantic. Twenty ships, fourteen of them steamers of the largest class, had to be built, equipped, and manned by the most experienced officers and crews that could be obtained. Arrangements of a far more comprehensive and complex nature than were necessary for a voyage to Halifax or New York required to be made; for though the voyage across the ocean was in both cases equally easy, yet the branch-lines of communication necessary to accommodate so many different islands could only be successfully wrought by a rare union of skilful arrangement and efficient management, of which the history of steam navigation afforded neither an example nor a guide. The fourteen vessels were named after the rivers of the country where they were built, as follows: *Thames*, *Medway*, *Trent*, and *Isis*, built at Northfleet; *Severn* and *Avon*, at Bristol; *T*— *Clyde*, *Teviot*, *Dee*, and *Solway*, at Greenock; *Tay*, at D—

barton; *Forth*, at Leith; *Medina*, at Cowes, Isle of Wight. The total cost of these ships was not much under a million sterling. The run from Southampton or Falmouth to St Thomas, in the West Indies, generally took about 18 days, and the same home. The company sustained very heavy losses in performing the service; six of their finest steamers were entirely lost: the *Solway* on a dark night after leaving Corunna in Spain; the *Forth* and the *Tweed* on the Alacranes rocks in the Gulf of Mexico; the *Actæon* in rounding the point near Carthagena in the Gulf of Darien; the *Isis* off Bermuda on her way home; and the *Medina* on a reef at Turk's Island, north from San Domingo.

On the expiration of the first mail contract a new one was entered into; and the terms and routes have since undergone many changes. The actual fleet belonging to the company in the summer of 1866, with tonnage and horse-power, presents the following particulars:

	Registered Tonnage.	Horse-power.		Registered Tonnage.	Horse-power.
Shannon	3472	800	Tamar	1707	400
Seine	3440	800	Solent	1689	400
Atrato	3126	800	Danube	1670	400
La Plata	2826	1000	Eider	1564	300
Douro	2824	500	Arno	1038	250
Rhone	2738	500	Mersey	1001	250
Parana	2730	800	Conway	895	260
Tasmania	2445	550	Derwent	794	260
Oneida	2284	530	Wye	752	180
Tyne	1916	400			

All these nineteen ships are named after rivers, except one, the *Tasmania*. It will be seen that not one of the steamers which started the service in 1842 is to be found in this list; all were lost, worn out, or transferred to some other service. In 1851 no steamer in the company's fleet was so large as 2000 tons register; but now there are six, the *La Plata*, *Douro*, *Rhone*, *Parana*, *Tasmania*, and *Oneida*, between 2000 and 3000 tons; while the magnificent *Shannon*, *Seine*, and *Atrato* exceed 3000 tons each. Seven out of the nineteen, including the three just

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named, are iron-built paddle steamers; six are timber-built paddle; and six are iron-built screws.

Concerning the routes which these steamers follow in delivering and receiving mails, passengers, and goods, the details are too intricate to be traced with any useful result here; but a general idea of them may be given. We must bear in mind that the scope of the scheme embraces the West Indies, Mexico, the republics of Central America, Brazil, and the Argentine Confederation, so far as concerns the ports on the Atlantic seaboard; of the Pacific ports, a little will be said afterwards.

A glance at a map of the West India Islands will shew that between the largest of these (such as Cuba, Jamaica, and Hayti) and the Atlantic Ocean, there is a long chain of islets stretching from the coast of Florida to the mouth of the River Orinoco, a distance of nearly 2000 miles. Almost in the centre of this chain, with its eastern shores exposed to the Atlantic, and its western to the Caribbean Sea, lies the little island of St Thomas, belonging to Denmark. Though only 37 square miles in extent, or about one-seventh of the size of the Isle of Man, its spacious and safe harbour has long rendered it one of the greatest commercial emporiums in the West Indies. This little island has been chosen as the great rendezvous for the West India mail steamers—the centre, as it were, from which radiate all the branch-lines of communication. It is to the West Indies and Central America what Southampton is to the British Islands and the continent of Europe. From Southampton a steamer sails on the 2d and 17th of each month, and after a direct voyage across the Atlantic of 3622 miles, arrives at St Thomas in 15 days after leaving England. The mails and passengers are then distributed among several steamers, which start off in various directions. Some of the mails proceed to cross the Caribbean Sea; and after steaming 690 miles, enter the excellent harbour of the old Spanish city of Santa Martha, on the north shore of South America; and then, in 105 miles more, the best and largest port on that coast, near the city of Carthagena, with its fine old cathedral, its public cisterns, and its traditions of the Spanish

and Sir Francis Drake. After further distances of 280 miles to the Panama Railway, and 280 to Greytown, the mails reach the mouth of the river San Juan, which connects the Nicaragua Lake with the sea. Another route is from St Thomas to the port of St Juan, in the Spanish island of Porto Rico. The distance is 65 miles. Then the steamer proceeds to Port Royal, the old capital of Jamaica, distant from St Juan 643 miles. In five days more the vessel has steamed 1118 miles, and arrived at Vera Cruz, a city built on the spot where Hernando Cortez first landed, and now the chief seaport of Mexico. After proceeding 250 miles northwards to Tampico, another Mexican seaport, the end of this route is reached. Jacmel in the island of Hayti, Havanna in the island of Cuba, and Belize in Honduras, are all visited once if not twice a month. Another route, although only 1838 miles from St Thomas and back again, involves calling at no fewer than ten places, some of them distant only 11 miles from each other. They are—St Kitts, a little island, the greater part of which is occupied by a mountain 3711 feet high, bearing the sad name of Misery; Nevis, an islet only 6½ miles long; Montserrat, another tiny island; Antigua, with an area of 108 square miles; Guadaloupe, the best of the islands remaining to France; Dominica, once French, but now British; Martinique, where Napoleon's Josephine was born; St Lucia, with its magnificent harbour; Barbadoes, one of the oldest colonies of England; and Demerara, on the mainland. There is a branch steamer at Barbadoes, ready to exchange mails, and proceed to Tobago by way of St Vincent; Carriacou, a very small island, from whence the mails are despatched by the inhabitants in a boat; Grenada, an island where the company have a coal dépôt; and Trinidad, the largest, except Jamaica, of the British West India Islands. The round from Barbadoes to Tobago and back is a distance of 702 miles.

The exact details of these voyages need not be given here; the general principle of the system will be sufficiently understood. The days and hours are calculated with great care, in order that all the home mails from all the islands and ports may reach St

Thomas in time for the return-journey to Southampton. For example, the mail that leaves Southampton on the 2d of every month reaches St Thomas on the 17th; and the mails by the aid of other vessels reach Barbadoes on the 20th, Jamaica on the 21st, Trinidad, Demerara, and Colon or Aspinwall (Panama Railway) on the 22d, Vera Cruz on the 27th, Carthagena and Tampico on the 28th, and other ports and islands on various dates. Whether large or small intercolonial steamers convey the mails, they must alike be timed so as to get the mails back to St Thomas on appointed days. The two great mails from Southampton leave on the 2d and 17th; the two from St Thomas homeward leave on the 15th and 30th. Jamaica, Barbadoes, Trinidad, Demerara, and Panama are accommodated by both mails; but the other islands and stations are placed in connection with only one mail each month, out and home. Speaking roughly, we may say that the steamers occupy a fortnight in getting from Southampton to St Thomas, a fortnight in delivering and collecting mails at the principal intercolonial stations, and a fortnight in the home voyage from St Thomas to Southampton—or six weeks altogether.

What a scene is Southampton Docks on the days of departure of the great steamers to the East and the West! And what a momentous affair is the commissariat, the 'bill of fare,' the larder, the list of eatables and drinkables, for one of these noble steamers! All have to be thought of, from the captain down to the cabin-boy, and the passengers whether first or second class; and all must be provisioned, not only for an out and home journey, but for the chance of detention on the way. Long experience has given the purser and steward an exact knowledge of the names and relative quantities of all the articles needed; while the provedore superintendent, on the part of the company, sees that the purser is furnished with these supplies before the ship starts.

Let us fix our attention on the supplies for one of the large West India mail steamers, which set forth from Southampton in the spring of 1866. By the courtesy of the authorities we

enabled to do this. First then, of *Bread and Meal:* there are [...] cwt. of cabin biscuit, 180 lbs. wine biscuit, 15 bags ship's biscuit, 50 barrels cabin flour, 336 lbs. oatmeal, 120 lbs. gingerbread nuts. Then *Groceries:* 415 lbs. tea, 700 lbs. coffee, 14 lbs. chocolate and cocoa, 3000 lbs. sugar for cabin, 5 casks sugar for crew, 960 lbs. currants and raisins, 270 lbs. figs and dates, 360 lbs. French plums, 55 lbs. pepper and spices, 614 lbs. rice, 48 lbs. arrowroot, 56 lbs. sago and tapioca, 100 gallons split peas, 4 bushels walnuts and Brazil nuts, 112 lbs. Normandy pippins, and quantities which we need not exactly specify of almonds, assorted essences, Barcelona nuts, candied peel, isinglass, farina, &c. Then come the multifarious articles included under *Oilman and Confectioner's Stores:* 200 lbs. candles, 300 lbs. jams, 400 lbs. marmalade, 800 lbs. salt, 130 quarts pickles, 100 lbs. maccaroni and vermicelli, 60 gallons vinegar, 500 lbs. soap, 112 lbs. soda, 40 lbs. mustard, and enough to stock several dealers with anchovies, blacking, bottled fruits, black-lead, chutney paste, cod sounds, curry-powder, dried herbs and seeds, emery-powder, gelatine, groats, red and salted herrings, hops, jellies, oil, volatile salts, olives, pearl-barley, capers, pickled mushrooms and ketchup, sardines, pickled salmon, sauces, soy, salt tripe, lemon-juice, whiting, Bath-bricks, rottenstone, and plate-powder. *Live-stock* figure to the extent of one cow and one calf, 50 sheep, 12 pigs, 300 fowls, 96 ducks, 36 geese, and 24 turkeys. *Dead Meat and Poultry* exhibit the items of 1000 lbs. beef, 300 lbs. suet, 3 carcasses mutton and 1 lamb, one carcass each of veal and pork, 30 ox-tails, 120 lbs. sausages, 120 fowls, 60 ducks, 24 geese, 30 turkeys, 60 pigeons, 60 rabbits. *Salted and Cured Meats* comprise 10 tierces salt beef, 224 lbs. corned beef, 12 barrels salt pork, 300 lbs. bacon, 50 hams, 250 lbs. Hamburg beef, 24 pickled tongues, 1 cask foreign tongues, 30 Bath chaps. *Preserved Provisions,* mostly in [...]-lb. tins, present a weight of 1200 lbs. of essence of beef, chicken and mutton broths, calves' head, jugged hare, giblet soup, mock turtle, mulligatawny, ox-tail soup, bouilli, salmon, French beans, vegetable and hare soups, haddock, herring,

carrot, green peas; together with 100 pints of oysters, and 11[illegible] pints and tins of dessicated and condensed milk. Then com[illegible] the *Fish*, for the saloon passengers: 100 lbs. cod, 100 lbs. turbot, 60 lbs. eels, 50 pairs soles, with haddocks and oysters. In *Cheesemongery* the chief items present themselves as 9 firkins Irish butter, 40 lbs. fresh butter, 1 jar butter, 48 North Wilts cheeses, 48 Dutch cheeses, 14 lbs. lard, and no less than 8000 eggs. Then we come to *Vegetables:* 60 cwts. potatoes, [illegible] barrels parsnips and turnips, 10 barrels carrots and onions, [illegible] barrels beetroot, 12 dozen horse-radish, 12 dozen cabbages, [illegible] bushels salad, 2 bushels parsley and water-cress, 1 lb. garlic, &c. *Fruit* is, of course, not a very large entry; yet it comprises 4 chests oranges, 4 barrels boiling-apples, 4 barrels dessert-apples, 60 lbs. grapes, and 50 lemons. As there are live-stock, there must be *Fodder;* and this comprises 18 bales hay, 6 sacks barley, 6 sacks barley-meal, 12 sacks oats, 3 sacks peas, 6 sacks bran, 1 bushel linseed. Now for that very important item, *Liquors*, occupying no small amount of space in the purser's domain. Those passengers who rise to the dignity of wine are supplied with 84 bottles port, 564 bottles sherry, 108 quarts still moselle, 144 quarts sparkling moselle, 108 quarts hock, 108 quarts sauterne, 180 quarts claret, 480 quarts medoc, and 162 quarts champagne. The spirit-drinkers are supplied with 180 gallons and 84 bottles rum, 50 gallons and 216 bottles brandy, 36 bottles hollands, 144 bottles whisky, 108 bottles gin. Then the drinkers of malt liquor find in store 1020 quarts ale, 2040 pints ale, 480 quarts porter, 1200 pints porter. Among miscellaneous beverages are 2400 bottles soda-water and lemonade, 360 pints Seltzer water, and 144 pints of various kinds of cordials and liqueurs. Lastly, among the odds and ends (b[illegible] which of course the provedore would dignify by some other name) are 300 lbs. tobacco, 500 cigars, 10 tons ice, and 6[illegible] packs of cards.

We have taken no account of the distinction between passenger provisions and crew provisions; hungry men claim the privilege of being fed on shipboard, whether they are fore

aft; and the provedore has to think of all of them. It will suffice if the above enumeration gives the reader some idea of the amount of forethought and care, registering and account-keeping, packing and stowing away, guarding and watching, called for in victualling one of our great ocean steamers, and supplying every one on board with all his eatables and drinkables from the time the ship leaves Southampton till it returns to the same port.

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§ X. CENTRAL AND SOUTH AMERICAN MAILS.

We must now present a few details concerning the operations of the Royal Mail Steam Company in South America, and of other companies in that region as well as in Central America.

On the 9th of every month a steamer leaves Southampton for Rio Janeiro in South America, where she is expected to arrive on the 5th of the following month. She steams across the stormy Bay of Biscay, and down the Portuguese coast until she arrives at Lisbon: after waiting a few hours she steams to Madeira, distant from Lisbon 535 miles; a fresh supply of coal, if required, is here shipped, and after waiting 12 hours, the steam is again got up, and the helmsman steers due south. Under the old contract, the mail steamer arrived near the far-famed Peak of Teneriffe in about a day and a quarter: six hours were spent here, and then the vessel ran along the African coast to St Vincent, one of the Cape de Verde islands, distant from Teneriffe 850 miles. A day and a half was spent here, and more coal shipped; and in little more than a week after leaving St Vincent, the steamer had crossed the Atlantic, and delivered her mails at Pernambuco, the third seaport of Brazil. In six hours she started off again down the South American coast to Bahia, and from thence to Rio Janeiro, the capital of Brazil, and the largest city of South America. A steamer was in waiting at Rio for the vessel from

England, whose southern mails she received, and then started for Monte Video, capital of the republic of Uruguay, distant from Rio Janeiro 1040 miles; after waiting a day and a quarter, she departed for Buenos Ayres, 130 miles up the mouth of the river La Plata, and arrived there in 16 hours. A fortnight after she started on the return-voyage to Rio Janeiro, there to meet the steamer returning to England.

Under the present contract, however, the service is managed in a somewhat different way. The steamers employed are larger and swifter, the number of places stopped at is smaller, the time consumed is lessened, and certain ports and islands are accommodated by other mail-routes. The fine large steamers *Douro*, *Rhone*, *Oneida*, and *Parana* are placed on the Southampton and Rio Janeiro route. One of these leaves Southampton on the 9th, gets to Lisbon on the 14th, St Vincent (Cape de Verdes) on the 22d, crosses the Atlantic, reaches Pernambuco on the 30th; thence to Bahia on the 2d of the following month, and to Rio on the 5th—twenty-six days after leaving England. At Rio a branch-steamer, the *Arno* or the *Mersey*, is ready to convey the mails further south, reaching Monte Video on the 14th, and Buenos Ayres on the 15th. The whole course of the mail to Rio is 26 days out, 4 days stop, 26 days home, or 56 days altogether. To Buenos Ayres and back, including all stoppages, the course of post is 82 days.

Thus the Royal Mail Steam Company, taking all its services together, embracing no less than 85 degrees of latitude, accommodate the whole of the Atlantic coast of America, from Mexico down nearly to Cape Horn; together with all the islands along the coast, and two points on the old continent.

Southampton by no means monopolises the steam-trade with the West Indies and South America. Liverpool claims a place, as is her wont, on every sea on the globe. In 1863, a company was formed with the long name, 'Liverpool, West Indian, and Central American Steam-navigation Company;' another called the 'Western and Spanish American Steam-ship Company;' and another called the 'West India and Pacific Steam-ship Company;'

These have gradually combined; and now a very important steam-trade is maintained between Liverpool and nearly all the important places in and around the Gulf of Mexico. They carry the mails to Honduras and Mexico; while Belize, Tampico, Aspinwall, Trinidad, Santa Martha, Barbadoes, Demerara, and other places, are visited by fine large steamers for passenger and merchandise traffic. The company's fleet is a large one, considering the recency of its formation; it comprises about twenty steamers, including the *Granadian*, *Chilian*, *Colombian*, *Cuban*, *Darien*, *Caribbean*, *Californian*, *American*, *West Indian*, *European*, *Venezuelan*, *Australian*, and *African*, some of them exceeding 2200 tons. So enterprising are now (1866) the operations of the company, that steamers run three times a month between Liverpool and the Isthmus of Panama.

The French are also doing something in this matter. The steamers of the 'Compagnie Générale Atlantique' keep up a monthly communication with the West Indies and South America.

§ XI. OCEAN STEAMING IN THE PACIFIC.

Ever since America was discovered, men have ardently wished that the Atlantic and Pacific could be connected by cutting through the Isthmus of Panama. The importance of such an undertaking, by shortening the voyage to China and other parts of Asia, as well as to Australia and the west coast of America, is obvious to all who cast even a hasty glance at the map; but the discovery of gold in California has rendered the cutting of the Isthmus an object of still greater interest. Two attempts were making about the year 1851 to cross this narrow strip of land: one by a railroad, the other by a ship-canal. The first of these was at Tehuantepec in Mexico, considerably to the north of Panama; the length of the railroad was to be about 136 miles, and the estimated cost £4,000,000. The other project was by the Lake of Nicaragua; its length about 110 miles, and its cost

estimated at £8,000,000. These projects were the subjects of several treaties, with the view of rendering the lines of canal and railway, when completed, great public highways for all the nations of the world. The treaty between Mexico and the United States with regard to the first, dated 23d June 1850, contained this remarkable stipulation: 'The line of route, with thirty miles on each side, shall be neutral in any war;' and in the convention between the United States and Great Britain, signed at Washington 19th April 1850, the object of the convention was declared to be 'that of constructing and maintaining the said canal as a ship communication between the two oceans for the benefit of mankind, on equal terms to all, and of protecting the same.'

In the meantime, however, the transit across the isthmus was by land, and the points of connection were Chagres on the east and Panama on the west. From the latter two lines of steam communication were organised—one to the north as far as San Francisco in California, the other to the south as far as Valparaiso; the mail service of the former being performed in American, and that of the latter in British vessels. The contract with the Pacific Steam-navigation Company came into force in 1846. The company possessed five steamers, the aggregate tonnage about 3000, and horse-power 995. The mails were carried once a month from Panama to Valparaiso and back, calling at Guayaquil, the chief seaport of the republic of Ecuador—Callao, the principal seaport of Lima—Arica, the outlet of a rich mining district of Peru—Copiapo and Coquimbo, also noted for their exports of silver—and at a number of ports of less note, thus establishing regular postal communication between all the civilised states of the western coast of South America. The distance steamed each year was 110,887 miles, and the sum received by the company, £20,000. The history of this company affords an example of the necessity of a mail contract to make ocean steam navigation profitable. In 1840, the projector, Mr Wheelwright, obtained from the local governments the exclusive privilege for ten years of conducting

the steam communication along the coast; but during the five years that the company were without the mail contract, the losses of the undertaking amounted to two-thirds of the paid-up capital. To Panama these vessels conveyed very large quantities of specie, the produce of the world-renowned mines of Peru; and to the same port the American steamers brought from San Francisco the produce of the gold-mines of California. All this silver and gold crossed the isthmus, and was re-shipped for Europe and the United States at Chagres. The value of the gold-dust brought by the steamers from California to Panama, from April 1849 to October 1850, was estimated at 25,000,000 American dollars, or about £5,000,000, being equal to the total value of the produce of *all* the American mines, both of gold and silver, in 1838.

The change actually made in the fifteen years which have elapsed since 1851, is less on the Panama route than on many others of our great ocean lines. The Mexican railway from Tehuantepec has gone out of consideration, and so has the canal in Nicaragua; nothing practical has been effected in reference to either of them, nor are any negotiations at present on foot. There is, however, a railway at Panama, now forming the great route from the Atlantic to the Pacific; this line is only 48 miles in length, from Colon or Aspinwall in the Gulf of Mexico, to Panama on the Pacific coast. It ascends by easy gradients towards the summit-level from either ocean. The construction, however, was attended with much difficulty; the interior, intensely and unhealthily hot, was fatal to large numbers of the labourers employed; while the first twenty-three miles had to be laid on piles or crib-work, and filled in with earth. Since the complete opening of the line in 1855, the trade has year by year increased; the total absence of anything like competition, and the enormous saving of time in adopting this route on the way to the Pacific, have tempted the Panama Railway Company to adopt a very high tariff of fares and freight; as a consequence, it is the most expensive line in the world to travel upon, as estimated per mile.

Panama is now a great port of departure for ships, mail steamers, and trading sailers. The Pacific trade, in connection with the West India mail steamers, is thus managed. The steamers arrive out at Aspinwall, at the Atlantic end of the Panama Railway, on the 8th and 22d of each month; and trains run on the railway to forward mails, passengers, and goods. Through-tickets are issued between Southampton and more than twenty Pacific ports; to some of which the mail and passenger steamers proceed from Panama twice a month, to others once. By this means the whole of the Pacific coast of America is accommodated, whether belonging to Chili, Peru, Bolivia, Ecuador, Grenada, Guatemala, Mexico, the United States, or British America. All sorts of money are taken by the companies, owing to the number of different states and countries accommodated—American eagles, American dollars, Spanish dollars, Chilian condors, Grenada condors, and gold or silver five-franc pieces. Some of these coins have a size and value far exceeding those of our sovereign; the Chilian condor is reckoned at 37*s.*, the Grenada condor at 39*s.*, and the American eagle at 41*s.*

Southward from Panama, the chief traffic is in the hands of the 'Pacific Steam-navigation Company.' The service is three times a month between Panama, Callao, and Valparaiso; and the days are so fixed that, when the steamers arrive at Panama, and the mails, passengers, and freight have been conveyed on the railway, they arrive at Aspinwall in time for the various mail steamers to Europe. The smaller Pacific ports of Guayaquil, &c. are accommodated only once a month in each direction. Northwards from Panama, the chief traffic is in the hands of the 'United States Pacific Mail Company.' Steamers leave San Francisco three times a month, stop at Acapulco and Manzanillo, and end at Panama; whence the mails, passengers, and freight, after crossing the isthmus by rail, are received at Aspinwall by Atlantic steamers belonging to the same company, which convey them to New York. Some of these voyages are timed so as to agree with those of the steamers from Aspinwall

to Liverpool; while others suit better with the route to Southampton.

Near and around Panama, in what is known by the general designation Central America, the steam traffic is mostly managed by the Panama Railway Company's Central American steamers. The steamers start twice a month from Panama to various ports in Costa Rica, Nicaragua, and Salvador, and end at San José de Guatemala; whence they return on stated days. These, like the two other groups of steamers, work in with several lines on the Atlantic, more or less conveniently.

The United States are not insensible to the value of the grand Pacific and its trade. A line of steamers was started early in 1866 from California to Sandwich Islands, to do the distance in about eight days.

But the most important mail Pacific route, so far as concerns the interests of England and her colonies, is that from Panama to New Zealand. After an abundance of negotiations, and many disappointments, a 'Panama, New Zealand, and Australian Royal Mail Company' has been founded, with a subsidy from the New Zealand government, and a probability of aid from some of the Australian governments. Four ships have been built for the main line, the *Mataura*, *Kaikoura*, *Ruahine*, and *Rakaia*, screw-steamers about 1600 tons and 400 horse-power; and these act in conjunction with several smaller screws from 400 to 900 tons. The large ships ply between Panama and New Zealand; the smaller between the several ports of New Zealand, and between that colony and Australia. When the West India mail steamers leave Southampton on the 2d of each month, and have conveyed the passengers and mails for New Zealand to Aspinwall, a transit is quickly made on the railway, and at Panama one of the new steamers is ready to receive the cargo. Leaving Panama on or about the 24th, the steamer spans the mighty Pacific, and reaches Wellington in New Zealand on the 21st of the following month; from thence, smaller steamers complete the transit to Auckland, Taranaki, Napier, Nelson, Pictou, Canterbury, Otago, and Bluff, in New

Zealand, and to Sydney and Melbourne in Australia. The time estimated is—Southampton to Wellington, 49 days; to Sydney, 57 days. The return-voyages are so managed as to time with the West India steamer, which leaves Aspinwall on the 7th, and gets to Southampton on the 29th. It remains to be seen whether a saving of 2000 miles over the Suez route to New Zealand for the mails and best-paying passengers, and of 4000 miles over the ordinary sailing-ship route for merchandise and low-fare passengers, will render the scheme permanently successful—aided as it is by a subsidy of £110,000.

§ XII. THE GREAT EASTERN STEAM-SHIP.

THIS most marvellous of all ships was fittingly designed by the engineer of the Great Western Railway—a daring man, whose genius shewed itself in many departures from the ordinary routine of his profession. But though Mr Brunel designed it, another engineer made the discoveries which suggested the adoption of a ship far larger than any before known. This was Mr Scott Russell. He set himself as a problem to be solved—What is the form of ship that will pass most readily through the water? and, as a consequence, What is the size of ship that can be worked most profitably in long ocean voyages? Mr Scott Russell, as an engineer at Glasgow, had his attention drawn, more than thirty years ago, to a scheme for propelling boats rapidly on canals; and he made many experiments as to the best form of boat for this purpose. Having communicated the result to the British Association, he was empowered by that body to continue his experiments, in conjunction with Sir John Robinson. Their allotted duty was—to determine the nature and laws of the different kinds of waves; to find the nature of the connection between the motions of waves and the motions of floating bodies; and to ascertain the form of floating body that would meet with least resistance. During a succession of years, Mr

Russell (for the labour mainly devolved upon him) made a series of valuable reports on the results obtained. He ascertained the existence of different kinds of waves, one of which, called by him the Great Primary Wave of Translation, he found to be the one which is most concerned with the movement of ships. He announced three propositions—that 'when a vessel passes along the surface of water with high velocity, it produces a wave of translation, moving with a velocity depending in some degree on the depth;' that 'whenever the velocity of a vessel becomes greater than that of the wave of translation, the vessel is carried along *on the top of the wave* with diminished resistance;' and that 'in a voyage by steam in the open sea, exposed to adverse as well as favourable winds, there is a certain high velocity, and high portion of power, which may be accomplished with less expenditure of fuel and of room than at a lower speed with less power.' Practical men at once saw that these propositions must be very important if true: seeing that they point, for every individual ship, to a certain definite velocity more profitable than any lower velocity. Experimenting further on the forms of waves, he arrived at a conclusion that the shape of the hull of a ship ought to bear a relation to these forms, the bow resembling the curvature of a wave of translation, and the stern the wave of replacement. Thus arose Mr Scott Russell's *Wave-form*, or *Wave-principle* for ships. No less than twenty thousand experiments were made before this result was definitely arrived at. Not only was the bow to resemble one form of wave, and the stern another, but the broadest part of the ship should be a little behind the centre, say three-fifths from the head and two-fifths from the stern. Dr Scoresby had meanwhile been making observations on the height and length of waves at sea; he found that waves vary from 100 to 600 feet horizontally from crest to crest, in the degrees of wind varying from 'a fresh sea' to 'a great storm,' in sailor language. One corollary from this curious fact is, that a ship 600 to 700 feet long would always rest on the crests of two or more waves, and would never 'break her back' by having the two ends unsupported over the troughs between

the waves. Yachtsmen, pirates, smugglers, and slavers, it was found, had approached very near the wave-form in their swiftest vessels: not because they knew anything about the form of waves, but because they had gradually hit upon the form of hull that gave them the highest speed.

Out of these observations, experiments, and trials arose eventually the *Leviathan*, or *Great Eastern*. In 1852, an 'Eastern Steam-navigation Company' was formed, to establish a steam-route round the Cape of Good Hope to Australia and India. In 1853, the directors announced to the shareholders an opinion at which they had arrived—that a steamer, to be profitable on such a route, ought to be large enough to carry coal for the whole voyage out and home, and to carry a large cargo of merchandise as well as passengers. The stopping on the way to take in coals would entail great loss of time, while the cost of coal at any foreign station would be very much higher than at Newcastle, Glasgow, or Cardiff. Basing their calculation on the researches of Mr Scott Russell and Dr Scoresby, they proposed an enormous steamer, 700 feet long, to carry nearly 1000 passengers, 5000 tons of merchandise, 15,000 tons of coal; and to make the voyage from England to Australia in 35 days, at freights and fares much lower than had ever before been possible in steam-ships. They engaged Mr Scott Russell to apply his wave-principle, and to build the ship at his own works at Millwall; while they employed Mr Brunel to devise a mode of applying Stephenson's tubular principle to the construction of the hull. A piece of ground was prepared, with piles driven 30 feet down, to rest the vast mass upon; and upon this ground the ship gradually developed itself during the years 1854–5–6–7, under numerous mechanical and financial difficulties.

Let us briefly describe the hull. The length is 680 feet between the perpendiculars, or 692 on the upper-deck; the breadth 83 feet, or 118 feet over the paddle-boxes; the height of hull 60 feet, or 70 to the top of the bulwarks. The weight of iron in hull 7000 tons; launching-weight, 12,000 tons; to

weight if full of cargo and passengers, 30,000 tons; to draw 30 feet of water at a maximum. (The width of Oxford Street would not be sufficient to receive the width of the ship, including the paddle-boxes; and Russell Square would not receive the length.) The bottom is quite flat for 40 feet in width, without any keel. The framework comprises 35 webs or ribs of plate-iron, each 3 feet wide, and immensely strengthened at the angles and junction; they extend from end to end of the ship, side by side at the bottom, and one over another at the sides; the distance apart varying from 3 to 5 feet; and they are crossed at intervals by similar webs, to which they are firmly riveted by angle-irons. A double wall or double skin of plate-iron, embracing the edges of these webs, makes the structure of the hull cellular, having an inner skin three feet within an outer. There are 10,000 thick plates to form the two skins, each having the proper degree of curvature according to its place in the ship; some of these are as much as 28 feet long by $1\frac{1}{4}$ inch thick, and weigh $2\frac{1}{4}$ tons each. Nearly 3,000,000 rivets were used in fastening the plates to the ribs and the angle-irons. Any one cell throughout the hull might be filled with water without its flowing into the next cell. The cellular structure ends about 5 feet above water-level, the hull being single for the rest of the height. The iron in the decks, the bow, the partitions, the walls, the casings, the supports, the angle-irons, is so large in quantity and tough in quality, that the whole fabric has vast strength. Ten partitions or cross-walls of thick iron-plate divide the interior into eleven compartments, each individually water-tight; and there are two longitudinal walls extending a considerable part of the length. What with the deck, the transverse walls, and the longitudinal walls, the interior is divided into seventy or eighty boxes—iron above, iron below, and iron around. To apply the wave-form principle, there is a bow of 330 feet, a straight midship of 120 feet, and a stern of 230 feet; and the interior partitions are made to conform to this arrangement.

Then for the engines, and paddles, and screw. Minor changes

have been made in these matters during the eventful history of the ship; but it will be useful to describe them as originally constructed. Brunel and Scott Russell agreed to have both paddles and screw, to obtain the advantages of both modes of propulsion. There are 10 boilers—four for the paddle-engines and six for the screw; each is as large as a fair-sized drawing-room, and has 400 brass flue-tubes 6 feet long by 3 inches diameter; and the furnaces beneath the boilers get rid of their smoke and products of combustion through flues and passages up to the funnels, of which there are five, 100 feet in height by 6 feet diameter. Each boiler, when full of water, weighs nearly 100 tons; and the coal-bunkers, when full, hold 12,000 to 15,000 tons, around and above the boiler-rooms. A monster steam-pipe, 45 inches diameter, conveys the steam from the boilers to the engines. Four steam-engines, in two pairs, work the paddles; they were made at Millwall; each cylinder, 74 inches diameter by 14 feet stroke, required 34 tons of molten metal to cast it. The paddle-wheels, worked by these engines, are 56 feet in diameter, by 13 deep, with paddles attached to 3[illegible] radii or spokes. The screw-engines were made by Boulton and Watt at Soho; there are four of them, with cylinders of 84 inches diameter, and 4 feet stroke; the pistons are 84 inches diameter, 27 inches thick, and are attached to rods $7\frac{1}{2}$ inches thick. The propeller shaft is 160 feet long, 24 inches diameter at some parts of its length, and carrying at its stem-end a screw or propeller 24 feet in diameter. As to the horse-power of the engines collectively, it is not safe to say much; the makers declared, when all was finished, that the united force of all the eight engines might be worked up to 11,500 horse-power on a stretch; but the nominal horse-power is much less than this.

Then, aloft, or above the hull. Here so many changes have been made, to adapt the ship to the requirements of her peculiar Atlantic service, that we can only speak of what was *intended* in the original plan. It was intended, then, that there should be six masts, five of iron, and one of wood, carrying 7000 yards of sail; that the masts, yards, gaffs, and large spars should be

plate-iron, strengthened inside with discs; that the shrouds and standing rigging should be of iron-wire rope; that the anchors, eight or ten in number, should some of them be as heavy as 7 tons each; that the chain-cables should collectively be a mile long, with links weighing 60 lbs. each; that there should be twenty small engines in various places, to pump water, fill the boilers, work the capstans, and do other work to save the labour of the crew; that there should be two screw-steamers—equal in size to the Thames penny boats—hung on davits abaft the paddle-boxes; besides twenty other boats, decked or undecked.

And the like may be said of the accommodation below stairs for passengers and cargo. As no attempt has been made to steam the *Great Eastern* to Australia or India, many of the proposed arrangements have not been wanted. So far as the construction of the hull is concerned, the 'potentiality' of the ship may be thus summed up. The seventy or eighty iron-walled cells into which the interior is divided, admit of greatly varying the ratios of first, second, and third class passengers, and cargo. A certain mode of adapting these would enable them to accommodate 800 first-class or saloon passengers, 2000 second-class, 1200 third-class, and 400 officers and crew—4400 altogether. Such a crew, for such an unexampled number of passengers, would be about one-third sailors, one-third engineers and stokers, and one-third domestics. Whether the saloon passengers were few or many, the saloons themselves have a height of 13 feet 'tween decks—a fact wholly unparalleled in ship accommodation.

Such is this wonderful ship, partly as she really presents herself at the present day, partly as she would be if the original plan were fully carried out. The launching-weight being 12,000 tons, extraordinary precautions had to be taken. The vessel was built sideways, or broadside towards the water, in order that the immense length might not be an obstacle to the launching; immense timber foundations had to be used; and sloping ways were formed on the timber, down which the vast mass might slide into the water. The launching, attempted November

3, 1857, failed; the apparatus for checking was too much for the apparatus for pushing and pulling, and the ship stuck half-way. After numerous abortive attempts, and the expenditure of £60,000 for labour and materials, the launching was effected January 31, 1858. The work of finishing and fitting went on slowly; the company had spent all their money, and could only raise more with great difficulty and on very disadvantageous terms. The name *Leviathan* had been changed to *Great Eastern*, and this to *Great Ship;* but the second name has remained the permanently popular one. In the autumn of 1859 the mighty fabric was still in the Thames, advancing slowly towards completion. Whether she would ever obtain enough passengers and cargo to pay for a voyage to Australia and back was a problem left for time to solve; a voyage to America and back was resolved on in the first instance. The ship left her moorings for the first time on September 7, and anchored for the night at Woolwich; on the 8th she went to the Nore, and anchored again. While off Hastings on the 9th, a tremendous explosion took place among the steam machinery, bringing ruin and even death on board; it would have shattered the hull of any existing ship excepting herself; when the ship reached Weymouth, there were seven dead on board, besides many others seriously injured. Mr Brunel died on September 15, and therefore did not live to see his noble ship brave the real perils of the ocean; for it was of course only a coasting voyage from the Thames to Weymouth. Having undergone repairs and alterations, the *Great Eastern* started on her first voyage across the Atlantic, leaving Southampton June 17, 1860, and reaching New York June 28. After being made a show-ship for some time, she returned, successful as a ship, but not profitable as a speculation; repairs and voyages occupied the rest of 1860 and the greater part of 1861. On September 9 in the last-named year, while on a voyage from Liverpool to America with 400 passengers and a large cargo (the best freight she had ever had), the *Great Eastern* encountered so terrible a gale out in the Atlantic, three hundred miles from Ireland, that

both paddles were swept away, the steering apparatus shattered, the luggage and cabin furniture thrown into confusion (two cows washed into the ladies' cabin !), and the whole ship so disordered that a return-voyage to Cork and Liverpool was a labour of much difficulty. After being again refitted, the *Great Eastern* in December acted the part of a troop-ship, carrying out the Guards to America in magnificent style, and in such comfort as soldiers had seldom before found on shipboard.

What this noble vessel was doing between the winter of 1861 and the winter of 1864, it is scarcely necessary to say. The company were plunged in financial difficulties of various kinds, and legal proceedings arising out of them. It was a change of fortune when a plan was formed for employing the *Great Eastern* to carry out the Atlantic cable in 1865—an enterprise which will come for notice in a later portion of this volume. What the future of the ship must be, events alone will shew. The superb qualities of the hull are undisputed; but there has been much discussion concerning her speed, immersion, economy of propulsive power, and other matters. That she will never pay in merely making voyages to and fro across the Atlantic, with passengers and goods, seems now to be admitted: the unavoidable working expenses being so vast. Either longer ocean voyages, of such distances as could not be managed by smaller ships without coaling on the way, or exceptional modes of employment like that of telegraph-cable laying, must be looked to, if the ship is to return any profit to the owners. She has had four commanders during her brief but eventful career—Captain Harrison (who was drowned in Southampton Water in January 1860), Captain Vine Hall, Captain Walker, and Captain (now Sir James) Anderson.

We may add, that the *Great Eastern*, after her return from the Atlantic in 1865, was subjected to the action of a curious apparatus for cleaning ships' bottoms—though Mr Cruikshanks's new patent material for preserving ships' bottoms from fouling is now likely to render such mechanical apparatus unnecessary. A rotating wooden cylinder, with spiral scrapers and brushes on

its surface, and capable of being lowered from the deck, was drawn up and down, and from side to side, against the outer surface of the ship, in such a way as to scrape and brush away all shells, barnacles, weeds, &c. Accumulations of such marine refuse greatly retard the progress of a ship through the water, and require to be periodically removed. It is said that three hundred tons of mussels, in some places lying eight inches in thickness, were scraped off the bottom of the *Great Eastern.*

The grandest ship in the world returned to England in September 1866, after completing the submersion of the grandest pair of telegraphic cables in the world.

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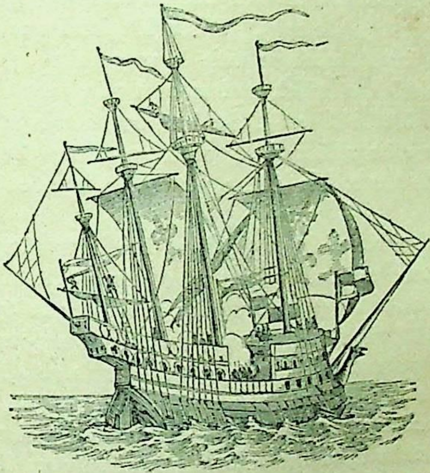
§ XIII. WAR-SHIPS: THE OLD SAILING FLEET.

Ships for trade—vessels ploughing the ocean in the cause peaceful commerce—rather than ships of war, are those which this chapter is mainly directed; but as each throws lig upon the other, we must devote a few sections to natio navies.

The English navy was established by Henry VIII. Bef his time, ships were gathered together from any quarter wh war was to be carried on, without provision being made for th maintenance afterwards. Henry built dockyards at Deptf Woolwich, and Portsmouth; he made laws for planting and p serving trees suitable for ship timber; he established the Tri House Corporation, for the improvement of the science and of navigation; he instituted the Commissions of the Admi and Navy; he made the navy a distinct and recognised branc the public service; and he organised the relation between several grades of officers and seamen. It could not but be many improvements in ship-building would flow out of such application of system to that which had before been unsystem The *Harry Grace de Dieu*, or *Great Harry*, the levia

ship of those days, was of 1000 tons burden, carrying 72 pieces of cannon, 350 mariners, and about as many soldiers; it was the first double-decked ship built in England. When, in the time of Elizabeth, an English fleet had to measure its strength against the whole power of Spain, the number of vessels amounted altogether to 170, with 15,000 men; but these were not all royal ships; many towns and many wealthy subjects came loyally



The Great Harry.

forward to the rescue. At the beginning of the next following century, when the Stuart dynasty opened, the Royal Navy consisted of 42 ships and 17,000 men. Ships were first divided into 'rates' and 'classes' by Charles I.: a system still continued, though in a greatly modified form. The *Sovereign of the Seas,* built at Woolwich by the unfortunate monarch in 1637, was the finest ship-of-war that had up to that time been seen. It was 232 feet long, 48 feet broad, 76 feet high from the bottom of the keel to the top lantern on the poop; there were 10 lanterns or light-rooms, so capacious that each would hold ten persons; three complete decks and two half-decks; 11 anchors, one of

40 cwt.; the burden was 1637 tons, and the vessel was pierced for 122 guns. This notable ship was cut down afterwards to improve the sailing qualities. It was nearly rebuilt in 1684 by Charles II., and the name changed to the *Royal Sovereign.* When the century closed, the Royal Navy comprised 154 vessels, 6930 guns, and 42,000 seamen.

During the eighteenth century, the royal ships of course gradually increased both in number and in size—to 198 in 1714, 325 in 1760, and 377 in 1785. When England was putting on her strength for a fierce war with France in 1803, she could boast of 970 ships, of which no less than 189 were ships-of-the-line, or line-of-battle ships. They were not, however, such ships as would now be reckoned of much account; the *Caledonia,* 120 guns, the master-ship of the year 1809, was only 205 feet long.

A *ship*, in mariner's language, is a three-masted vessel carrying square sails suspended from yards on each of the three masts; a *bark*, or *barque*, has square sails only to the fore and main masts, but not to the mizzen; a *brig* is a two-masted vessel with square sails on both masts; a *schooner* is also two-masted, but with the sails on the mizzen fore-and-aft, or in a line with the keel; a *cutter* is a single-masted vessel, with fore-and-aft sails; a *sloop* resembles it, except in having relatively smaller sails; a *brigantine* and a *snow* are modifications of the brig; a *lugger*, a *ketch*, a *gig*, a *pinnace*, a *long-boat*, a *barge*, and numerous others, occupy medium ranks between the ship and the mere boat. Concerning ships-of-war, they were in past days divided into six classes or 'rates,' according to their size and armament. A *first-rate* carried 100 guns or upwards, and 800 or 900 men; a *second-rate*, 90 to 100 guns, and 600 to 700 men; a *third-rate*, 60 to 80 guns, and 550 to 650 men; and so on. All these were called *ships-of-the-line*, intended to take up a position in line of battle; while other vessels, under the names of *frigates* and *corvettes*, were adapted for detached and more varied service.

A first-rate line-of-battle ship of 120 guns, in the latest perfected form previous to the introduction of steam, presented the

following general features. There were several decks, running either the whole length or part of the length. The ship was a sort of six-storied tenement, with a seventh story at one end. First or lowest was the *hold*, a vast space appropriated to ballast, stores, and provisions; it was divided by bulk-heads or partitions into several sections, such as the bread-room, salt-meat store, spirit-room, powder-room or magazine, light-room, and compartments for shot and shell, boatswain's stores, carpenter's stores, water-tanks and casks, &c. Above the hold was the *orlop deck*, on which were constructed the purser's room, surgeon's room, cockpit or surgeon's operating-room, chief boatswain's and carpenter's berths, and midshipmen's mess-room; besides arrangements for accommodating a vast store of cables, cordage, and sails. Over the orlop deck was the *lower deck*, the sanctum of the sailors, where they mostly ate and drank, sang and slept, with the port-holes and big guns close to them; on a level with this deck, or occupying the stern end of it, was usually the gun-room—the common mess-room for officers below the rank of lieutenant. Next above the lower deck was the *middle deck*, kept pretty well clear for the operations of the seamen-gunners who were to bang away with their great guns against the enemy, but having at the stern end the ward-room, a sort of lieutenant's saloon or dining-cabin. Over the middle deck was the *main deck*, occupied by the admiral's state-cabin at one end, and near the other end the cook's room and the sick-room. Above the main deck, at various parts of the ship's length, were the *captain's cabin*, the *quarter-deck*, the *gangway*, and the *forecastle*, all open overhead except the captain's cabin. Lastly, over this cabin, and forming the seventh of the series of elevations, was the *poop*, on which the marines stood. Running entirely up through those successive ranges were the three masts, the *fore*, *main*, and *mizzen*; and each of these was built up to a great height by sections placed nearly end to end, called the *lower*, *top*, and *top-gallant* masts. Enormous *yards* or horizontal beams were arranged for sustaining the sails; and a *bowsprit*, with its *jib-boom*, for carrying jib and fore sails. The sails were very varied

in size and shape, not less than fifty altogether, used in various combinations according to the strength and direction of the wind. The rigging was still more complex, with its *lanyards*, *shrouds*, *ratlines*, *stays*, *back-stays*, &c.; besides the ponderous hempen cables, sometimes as much as 24 inches in circumference, and intended each to govern and retain anchors of 90 cwt. Such a ship carried a hundred and fourteen 32-pounders, four 80-pounders, and two 68-pounder carronades.

The living freight of such a ship was classified with the most careful minuteness. The aristocracy of the community included the captain, commander, lieutenants, master, chaplain, surgeon, and purser; then came the second master, assistant-surgeons, gunner, boatswain, carpenter, and mate. The midshipmen, or 'middies,' or 'young gentlemen,' were to become officers by and by. Then masters' assistants, schoolmaster, clerk, master-at-arms, ship's corporals, coxswains, quartermasters, gunner's and boatswain's and carpenter's mates, cook, sail-maker, rope-maker, caulker, and armourer, made about five-and-twenty persons. Next came the 'crews' or working-hands under the orders of the gunner, carpenter, sail-maker, cooper, armourer, &c., with the various stewards, cooks, and boys. Lastly, 160 marines or soldiers—captain, lieutenants, sergeants, corporals, drummers, and privates—added to the 690 blue-jackets, made up the complement of 850 men that lived and worked, fought and slept, played and prayed on board a first-rate.

Captain Basil Hall's description of 'Sunday on board a man-of-war,' gives an admirable notion of the discipline and the scrupulous attention to cleanliness observable in our sailing war-ships just before the days of steam. 'Few landsmen can form any idea of the fastidious cleanliness in which every part of a ship is kept. No floor of a palace is so white, no parlour of a lady is so neat, as the decks of a man-of-war on Sunday morning. The planks, which are scoured and swept every day of the week, receive a double portion of washing on Saturday. At seven o'clock the hammocks are 'piped up;' when each man brings up his bed, scrupulously folded, and packed in the neatest

manner, and places it in the nettings. When these preliminary steps are gone through, and every rope is coiled up in its proper place, the sailors go to breakfast, during which the word is passed to "clean for muster;" and the dress is specified according to the time of year and climate. Thus, at different seasons, is heard: "Do you hear there! fore and aft! clean for muster at five bells; duck frocks and white trousers!" or, "Blue jackets and trousers!" or, "D'ye hear there! clean shirt and a shave for muster at five bells!" At half-past eight the first watch is called; between decks, the store-rooms, and, indeed, every hole and corner, is then swept, and put into the nicest order; all which is accomplished by half-past ten. The mate of the decks, the mate of the hold, the boatswain, gunner, and carpenter having previously received reports from their subordinates, that the different departments they superintend are ready; and reports being then finally made to the first-lieutenant by the mates and warrant-officers, he himself goes round the ship to see that all is ready for the grand inspection.' This inspection consisted in a visit by the captain and first-lieutenant to every part of the ship, to see that all was clean, healthy, and orderly. Then for church. 'The quarter-deck is the place of worship. The pulpit, which is either one of the binnacles, or sometimes a stand of arms, is placed in the middle and covered over with a flag; and a quantity of gun-wadding is placed on a canister of shot to make a hassock for the chaplain (or the captain, if there be no divine on board) to kneel on. Chairs from the captain's cabin and ward-room are set for the officers; and the men sit on their mess-stools, or on the gun-carriages, or on capstan-bars resting on tubs, but all in due order and subordination, and with the utmost decorum. The awnings are spread overhead to keep off the sun if the weather be fine; but in rainy or squally weather the church is prepared on the main deck, aft under the quarter-deck. A pendant is hoisted to indicate that prayers are going on; and this signal is respected by every other ship during the continuance of service. The dinner-hour is always at noon; but on Sunday the people are

left undisturbed till four o'clock, to read or recreate themselves in any way they please; but that which especially characterises Sunday afternoon on board, is the cessation of all the noise and stir caused by the various occupations of the artificers and crew. The men either gather in groups on the deck, talking and telling stories, or fall asleep; or walk up and down the lee-gangways and forecastle. This inactivity, contrasted with the usual animated bustle on board, is a distinguishing mark of the day of rest.' A few duties devolved upon the men after four o'clock; but they were usually rendered as light as possible.

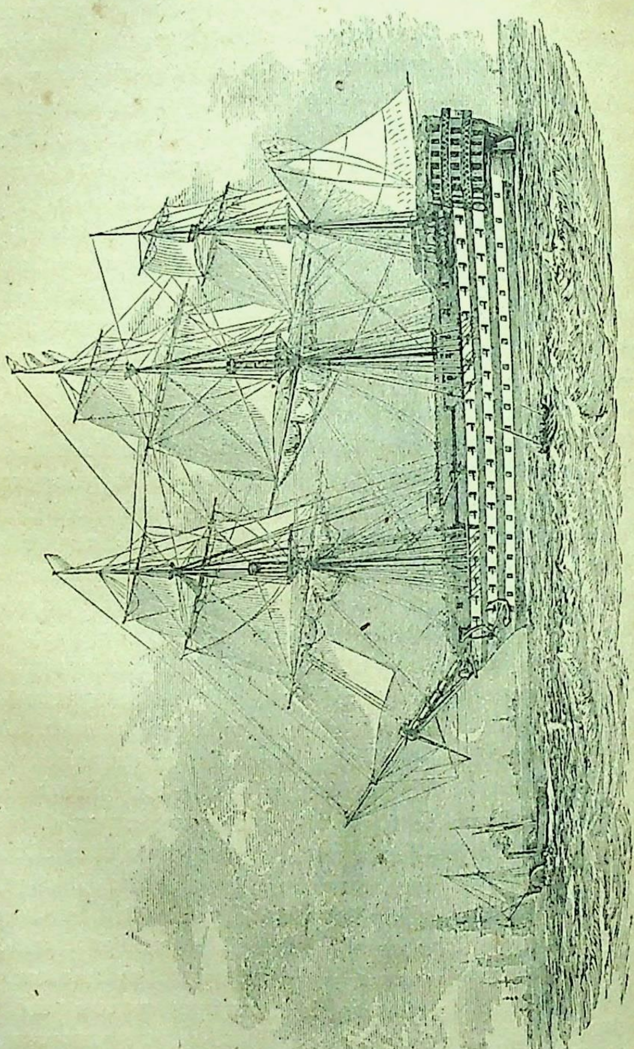
§ XIV. WAR-SHIPS: THE PADDLE AND SCREW FLEET.

So many things have changed in the world of the royal navy since the days when Basil Hall wrote, that the old routine has undergone surprising modifications. Iron ship-building has effected some of this, but steam has effected much more.

In 1815, the Admiralty ordered a steam-engine to be put into the war-sloop *Congo*, but the order was countermanded; and the first steamer actually possessed by the government was the *Monkey*, purchased in 1821. Then the *Comet* was built at Deptford, and then several other paddle-steamers, mostly of small size. Sir William Symonds, surveyor of the navy, took up the steam-ship department in 1832; but the war-steamers of those days satisfied neither naval men nor engineers. In 1837, Captain Ericsson proposed the screw-propeller to the Admiralty, as being less exposed to hostile shot from enemy's guns than the large projecting paddle-box and paddles; not being listened to, he went to America, where he commenced a screw navy for the United States. In 1840, Mr Smith drew public attention to the screw-propeller by the excellent performance of his *Archimedes*; it was not, however, till 1845 that a government screw-ship, the *Rattler*, was fairly compared with a paddle-

ship, the *Alecto*, and came off with the palm of superiority. Screws and paddles were now alike built for a few years; but the screw gradually superseded the paddle, especially for large war-ships. Sir William Symonds fought against the screw till 1847, when he was forced to yield to the judgment of others. Shortly before this, the Admiralty had begun to buy (not to build) iron ships-of-war; and then they proceeded to build for themselves, but without subjecting the ships (paddle-steamers) to the test of actual service. At length it became evident, after many experiments, that iron, though on the whole better than wood for commercial ships, is not so good for war-ships; and thereupon the building of iron paddle-steamers was stopped in 1850.

It is curious, knowing what the British fleet is composed of in 1866, to look back to the constitution of the fleets which took part in the grand naval reviews at Spithead in past years. When Sir Hyde Parker's experimental squadron assembled there in 1845, it consisted of sailing-vessels only, with the exception of a few small paddle-steamers; there were eight of the old line-of-battle sailing-ships—viz., *St Vincent* (120), *Trafalgar* (120), *Queen* (110), *Rodney* (92), *Albion* (90), *Vanguard* (84), *Canopus* (84), and *Superb* (80). In the year 1852, the political horizon looking cloudy, the government hastened forward some screw-steamers which were in hand, and ordered more to be built at once. A naval review at Spithead in 1853, shewed how extensive the changes had been. The largest ship in the navy had been launched at Pembroke in 1852; it was a screw-steamer, called first the *Windsor Castle*—the name being afterwards changed to the *Duke of Wellington*. She mounted 131 guns, and was, in 1853, regarded as the finest war-ship in the world. A second, like her, but to be called the *Marlborough*, was building at Portsmouth. Another ship, the *Agamemnon*, 91 guns, spread more canvas than any other ship in the service, near upon 11,000 yards. There were assembled altogether at Spithead 10 screw-steamers, from 131 down to 14 guns; 4 paddle-steamers of 22 down to 2 guns, and 4 sailing-ships from 90 guns (the *Prince Regent*



The Duke of Wellington, 131 Gun Screw-steamer.

and the *London*) down to 12. When Sir Charles Napier sailed for the Baltic, early in the Russian War of 1854, he had with him 8 screw line-of-battle ships, 4 screws of smaller rank, and 4 paddle-steamers, but not one sailing-ship. Later in the year, when Sir Charles's ships had all assembled in the Baltic, they were 29 in number—all steamers. In the Baltic fleet of 1855 there were 50 steamers, besides gun-boats, mortar-boats, and craft of minor character; seven were screw-steamers of more than 90 guns, 12 between 60 and 80, 10 between 20 and 50, and the rest under 20 guns. All the larger ships were screws; some had been expressly built as steamers; while others had been wooden sailing-ships, finished or partly finished, but altered to adapt them to the new order of things. The *Royal Albert*, a second 131-gun screw, was launched in 1854; and the *Marlborough*, the third, in 1855. This last-named ship of the first rank, as known in the days of the Russian War, was 246 feet length of keel, 283 feet length over all, 61 feet breadth, 26 feet depth of hold, highest point of hull above load-water level 40 feet, extreme height of truck of mainmast above load-water level 213 feet, burden 4000 tons, load draught of water 26 feet, weight of mainmast 23 tons, length of main-yard 111 feet, weight of anchors 23 tons, weight of rigging 93 tons, weight of guns and ammunition 600 tons, power of steam-engines 800 horse-power. All these great screw-steamers carried sail, and some of them spread an immense area of canvas.

In 1856 and 1857 more steamers were constructed, of various sizes, shapes, and power. Towards the close of 1858, the British navy consisted of 201 sailing-vessels, few of them ever likely to be commissioned again; 75 paddle-steamers, available for various miscellaneous services in war and peace; 51 line-of-battle screw-steamers; 28 screw-frigates; 21 screw-corvettes; 9 screw block-ships; 27 screw-sloops; and 228 mortar frigates, floating-batteries, gun-vessels, and gun-boats. Not only did the screws far outnumber the paddles, but they comprised the ships which are wont to take the front of battle in actual naval warfare. Some of the 50-gun screw-frigates were of one-fourth greater

tonnage than the largest line-of-battle ships of Nelson's days; and the guns themselves were such as had never before been used in broadsides.

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§ XV. WAR-SHIPS: THE IRON-CLAD FLEET.

No sooner do we escape from the year 1858 than we find a sudden check to the building of these magnificent screw-ships of 80 to 131 guns. Some of those actually in hand were to be finished; but the laying down of new ones was stopped by nothing less than a naval revolution. The reign of *iron-clads* or *armour-plated* ships began about 1859 or 1860. Iron-clads are not new; but the idea is new of combining a ponderous armour-plating with swiftness of steaming. Long before any one had thought of building ships of iron, battering vessels had been coated with thick plates of iron: something of this kind was known to the ancients; and something more definite was proposed by Mersenne two centuries and a half ago. Montgery wrote on the subject about 1820, and Paixhans at a later date. In 1842, Mr Balmano, of New York, addressed a letter to the Earl of Aberdeen, alleging that plates of iron $\frac{3}{8}$ths of an inch thick, riveted one upon another to an aggregate thickness of 6 inches, would be shot-proof. For some reason or other, the English government did not deem the matter worth prosecuting. Again, about the year 1848, Mr Stevens, an eminent iron-ship builder of New York, communicated to Mr Scott Russell some plans of his about iron-clad war steamers. Many other persons had plans and projects on the subject. At length, when the Russian War broke out in 1854, the Emperor of the French astonished Europe by sending to the Black Sea steam floating batteries plated over the whole exterior with thick slabs of iron. England, at once following the example, built eight ponderous batteries, clad with $4\frac{1}{2}$-inch iron armour; vessels that were found

to be very slow, very unmanageable, and weak in the timbers that supported the armour. After the launching of these batteries in 1856, the Admiralty were inundated in 1857 and the two following years by all sorts of suggestions concerning iron-clad war-ships. Mr Reed estimated that the ships of the Royal Navy, as they stood in 1858, had cost the country not less than £28,000,000; and the Admiralty, afraid to believe that such costly property was destined to be superseded, and bewildered by the multiplicity of counsellors, did nothing. Yet it was known, from experience gained during the Russian War, that horizontal shell-firing had overturned all the old theories about the strength of ships; that gun-and-shot making had advanced more rapidly than ship-building; and that wooden ships for war service would no longer be safe unless protected by an iron armour.

The first circumstance which drew the attention of England forcibly to the subject was the construction of the French ship *La Gloire*. This was a timber-built war-ship, originally intended for a 90-gun three-decker; but it was altered to an 'exaggerated corvette,' with one line of guns, twenty on each side. She was about 250 feet long by 55 beam, and when iron-clad with armour-plates 4½ inches thick, was reckoned as a 3000-ton ship. It was in the autumn of 1860 that this plated ship attracted the attention of European ship-builders and maritime governments.

One of the questions that directly presented themselves was, whether an English iron-clad fleet should consist of wooden vessels plated over, or of ships regularly built up of iron. It was decided to adopt both. One by one several large timber-built men-of-war were stopped in their progress towards completion, and handed over to the iron-workers. They were cut down to a much lower height above water; they were cut in two amidships, and lengthened by the insertion of additional framing. The *Caledonia*, *Ocean*, *Prince Consort*, *Royal Oak*, *Royal Alfred*, *Royal Sovereign*, *Favourite*, *Enterprise*, *Zealous*, and *Research*, all were treated in this way; they had mostly been laid down as 90-gun or 100-gun ships of the line; they were all about 275

feet long by 58 beam when altered; they all received armour generally $4\frac{1}{2}$ inches thick, backed by about 30 inches of solid timber; and they all ranked as about 4000 tons. Some of them have *rams* at the stem; that is, swan-breast projections of solid iron, which would crush an enemy's vessel if brought against it with any force. The *Lord Clyde* has a ram projecting 18 feet, 4 feet of solid iron backed by 14 of massive timber. Some of the ships are plated from end to end; whereas others, with a view to greater buoyancy in the water, are plated only amidships, where an enemy's broadside would have the most serious effects. This has been, from first to last, one of the vexed questions relating to the iron-clads; and it is not even now finally decided whether it is better to protect the ends at the expense of buoyancy and quickness, or to regard the two latter as more important qualities. The *Royal Oak*, like some others of this group, instead of the 92 guns originally intended, carries four 8-inch, and sixteen 7-inch rifled guns; the plates run from end to end, from the bulwarks down to 6 feet below the water-line; there is an armour-plated pilot-house abaft the mainmast; the screw weighs 11 tons, and has a diameter of 19 feet, and a pitch of 27; the furnaces will burn 100 tons of coal per day when in full steaming. The *Ocean* is one of those which were originally intended for 100-gun ships; she is nearly as sharp at the stern as at the bow, to test a theory as to this kind of build; the iron plates with which she is clad weigh more than 900 tons. The masts and bowsprits of these ships are mostly of iron. All has been done at the government establishments; the *Royal Oak*, launched in the autumn of 1862, was the first finished of its class, and the first iron-clad managed wholly by the government.

We have mentioned the names of certain iron-clad timber ships, some of which have been expressly built as such, while others were originally intended as two or three deckers of the old build, and then converted into monster frigates or corvettes. But these by no means exhaust the list of such vessels. The *Royal Sovereign* has been a subject of more discussion in parliament than almost any other ship. Captain Cowper Coles, a few

years ago, invented a kind of turret, cupola, or shield, to contain one or two monster guns on shipboard. After much correspondence, the Admiralty intrusted to him the *Royal Sovereign*, a first-rate three-decker converted into an iron-clad. He built four turrets that projected upwards of 4 feet, and were made of 5-inch iron plate, backed by 20 inches of teak. There are two 9-inch guns in the largest turret, and one in each of the others. Every turret is so pivoted, that it can be made to revolve with its gun, and thus enable the gunners to point their guns in almost any direction. The port-holes in the turrets are only just large enough for the due working of the guns; and the turrets are quite closed at the top with thick plate, except by a man-hole as a look-out. This armour-plated and turret-gunned ship was launched on 8th March 1864; and its merits and demerits, in reference to sea-worthiness, roominess for officers and crew, steadiness in rough weather, height out of the water, rate of speed, readiness to answer the helm, and facility of working the turret-guns, have been very amply discussed. In June 1866, this ship bravely withstood one of the severest tests ever applied: one of the turrets was fired at by a 12-ton 9-inch gun at a short distance, with heavy charges and steel shot; the turret, partly owing to its immense strength, and partly to its cylindrical form, bore the fearful hammering with very little injury.

Of the other armour-plated timber ships above named, the *Pallas* was designed to try whether an iron-clad might be made of moderate size, and yet high speed; it was therefore built as a corvette of only 8 guns, four of which are formidable 8-inch guns, weighing 9 tons each. The sides of the vessel are so constructed, that the guns, although not in turrets, can be fired at almost any angle, except directly ahead or astern; and there is a powerful ram at the bow. The interior of the ship has been planned so as to give more accommodation to the crew than is afforded by many of the iron-clads. Being 1300 tons less ponderous than the *Defence* class of iron-clad frigates—which are found to be very slow—this *Pallas*, designed by Mr Reed, and

launched at Woolwich in March 1865, is regarded as an experiment likely to solve several problems, and to yield several kinds of service. Amongst the smallest of the $4\frac{1}{2}$-inch armour-plated vessels are the *Viper*, *Vixen*, and *Waterwitch*, gun-boats of about 750 tons each; the *Viper* and *Waterwitch* are wholly of iron.

For clearness of description, we have treated the iron-clad timber ships in two groups, without touching on the other principle of construction. This will enable us all the better to proceed with the far more important, or at least far more costly, armour-plated iron ships, built expressly as iron-clads.

One of the first things done by the Admiralty, on the incentive given by the French *La Gloire*, was to order iron-clads of a new and formidable class—the *Warrior*, *Black Prince*, and *Achilles*, each to exceed 6000 tons burden, with engines of 1250 horse-power; to have very large guns; and to be clad with armour-plates $4\frac{1}{2}$ inches thick, backed by 18 inches of teak. The *Warrior*, the first finished of the three, was built by the Thames Company at Blackwall, and handed over to the government in 1862. It was the first iron-clad built wholly of iron. As it was calculated that the total weight, with engines and boilers, guns and stores, would reach nearly 10,000 tons, vast strength was required in every part, and numerous modifications were made while the ship was in progress. The guns are 9 feet out of the water—3 feet more than those of *La Gloire*. There are 10 boilers, containing 4400 brass tubes for heated air; 40 furnaces, that will burn 130 tons of coal a day; and a screw-shaft 130 feet long by 17 inches diameter. The engines were the largest ever made up to that date for a man-of-war, with cylinders 112 inches in diameter. By means of thick iron-plate walls, the ship is divided into thirty water-tight compartments, an arrangement that immensely increased the safety of the ship in cases of collision or grounding. The guns are formidable—four 8-inch and twenty-eight 7-inch rifled guns—32 in all. The bow and stern are so subdivided by the iron partitions above mentioned, that they might be riddled with shot without much danger to the other parts of the ship. The

armour is not carried from end to end; it is confined to the broadside amidships. It was a great satisfaction to the builders and to the Admiralty that this vast fabric proved to be a fast, buoyant, and easy-going ship. The *Prince Albert*, a turret-ship, was finished in 1864. The *Achilles*, first officially tried in 1864, was launched at Chatham. She displaces no less than 9525 tons when loaded to 23 feet draught. The port-holes are 12 feet above water-level. Her average speed at the first trial was $14\frac{1}{3}$ knots, or nearly 16 statute miles per hour—faster than any other iron-clad afloat. She had, however, a clumsy, old-fashioned, steering apparatus, which required sixteen men to work the helm. Mr Gisborne's excellent electric apparatus was introduced on board, to send telegraphic messages between the pilot and the engineers.

Probably nothing less than actual warfare will settle the relative merits of two celebrated triads of armour-plated ships—the *Warrior*, *Black Prince*, and *Achilles*, just mentioned; or the *Minotaur*, *Agincourt*, and *Northumberland*, the largest ships in the world excepting only the *Great Eastern*. The Admiralty decided on these enormous ships in the autumn of 1861, but it was not until 1864 that any of them were finished. The *Minotaur* was undertaken by the Thames Company at Blackwall, the *Agincourt* by Messrs Laird at Birkenhead, and the *Northumberland* by the Millwall Company. They were intended as an improvement on the *Warrior* class—all to be of nearly 7000 tons, 400 feet long, 59 feet beam, and propelled by engines of 1350 horse-power; with a swan-breast ram protruding from the bow below the level of the water. This stem-ram, and the huge iron beam which forms the stern-frame, were to be among the largest forgings ever made. The division into water-tight compartments was to be so managed as to guard against accidents below the water-line, and at the same time to increase the stiffness of the whole fabric. The Admiralty, having formed a notion that another inch of iron would be more than an equivalent for many inches of timber, decided on $5\frac{1}{2}$-inch plates with 10-inch backing of teak, instead of the $4\frac{1}{2}$-inch iron and 18 inches

teak adopted in the *Warrior* class. When the ships were somewhat advanced, experiments were made which shook the confidence of the Admiralty. Exposed to equal tests at Shoeburyness, a target on the *Warrior* plan bore up bravely, while one on the *Minotaur* plan literally crumpled up under the fire of a smooth-bore 68-pounder. This led many experienced men to the conviction that a very thick backing is more important than a slight increase in the thickness of the plate—at least in the ratios adopted in these two ships; but the *Minotaur* and her companions were too far advanced to allow of any material change of plan. Although armour-plated throughout their whole length, Mr Penn believes that his steam-engines will give these monster ships a speed of 16 knots an hour; if this should be realised, they will be not only the largest but the fastest iron-clads yet built. The *Northumberland* is not quite so heavily plated as the *Minotaur* and *Agincourt;* at the bow and stern there is only a belt of plate, a little above and a little below the water-level, instead of the same height as at midships—a change which Mr Reed is said to have imitated from the French iron-clads *Magenta* and *Solferino;* the belt is 10 feet wide for 100 feet at the stern-end, and 8 feet wide for a similar length at the bow-end, there being in each instance about an equal quantity above and below water. The 200 feet of midship has $22\frac{1}{2}$ feet width (or rather height) of plating, 16 feet above and $6\frac{1}{2}$ feet below water. The bulkheads or partitions to separate the midship from the two ends are no less than $4\frac{1}{2}$ inches thick of solid iron, extending from the floor of the main-deck up to the spar-deck. There is a semicircular shield of $4\frac{1}{2}$-inch iron running completely across the bows at the forecastle; and there are to be two guns of the heaviest calibre in this shield, to be used as 'bow-chasers' pursuing directly in the wake of an enemy. The port-holes of the broadside guns will be 10 feet above the water-level, when the ship is fully loaded. There will be 4 twelve-ton 9-inch guns, and 22 nine-ton 8-inch guns. On the deck is a tower of wood and iron, divided into two stories, the lower for riflemen, the upper for commanding and steering.

Since it was begun, the *Northumberland* has had a poop added, to give additional accommodation for officers, which is believed to be rather deficient in the *Minotaur* and *Agincourt*. There is also a top-gallant forecastle added, for the additional comfort of the crew. The officers and crew together will be 750 in number. There are five iron masts, four square-rigged and one fore-and-aft. It took 30 tons of molten iron to cast the cylinders of the steam-engine. The *Minotaur* and the *Agincourt* were handed up by the respective builders to the Admiralty in 1865. The *Northumberland*, which the public have heard most about, failed in the launching in March 1866, owing to a miscalculation in the slope of the launch-ways; having all the armour-plates on, it was the heaviest ship ever attempted to be launched (except the *Great Eastern*), weighing 8000 tons. The launch was, however, successfully effected in the next following month.

Besides these two magnificent triads of iron-built iron-clads—the *Warrior* class and the *Minotaur* class—the Admiralty possess nearly a dozen others, varying greatly in size and build. The *Bellerophon* has an exceptional thickness of 6-inch armour, backed with 10 inches of teak, and is in the same predicament as the *Minotaur* class, in having a timber backing which is now believed to be too weak. The *Hector*, *Valiant*, *Defence*, and *Resistance* form a group by themselves; each about 4000 tons, from 600 to 800 horse-power, with $4\frac{1}{2}$-inch plating, backed by 18 inches of teak. Or, more exactly, we may say that the *Hector* and *Valiant* form one pair, rather over 4000 tons, 800 horse-power, and carrying 18 guns; while the *Defence* and *Resistance* form another pair, rather under 4000 tons, 600 horse-power, and 16 guns. The *Resistance* was the first finished of the four, launched in 1861 from the yard of Messrs Westwood and Baillie; while the *Defence*, built by Messrs Palmer of Jarrow, was the first iron-clad that had a ram. The *Hector* and the *Valiant* were planned to have intermediate qualities between those of the *Warrior* class and *Defence* class: the *Defence* class are not plated at the ends, whereas the *Hector* class carry armour-plates from stem to stern, and are very sharp

at the stern as well as at the head; they have also a semicircular shield at the bows, like the *Northumberland.* These four ships have had a large amount of hard language to bear; one critic has gone so far as to say that 'two of them could not face the sea, the other two could not face the enemy.' The test of actual war has, of course, not been applied to them. The *Prince Albert* is a 6-gun sloop of about 2500 tons, with a turret; and is thought an interesting experiment in connection with this peculiar style of construction. The *Scorpion* and the *Wyvern* are those identical 'Confederate rams' which occasioned so much worry and vexation to the government during the civil war in America. They were at first known as *El Monassir* and *El Toussin;* but when the English government purchased them to avoid further wrangle about them with the United States, the names were changed. They are 1900-ton vessels, clad with armour-plates varying from $4\frac{1}{2}$ to 2 inches thickness in various parts, backed with nine inches of teak. They have double sides and double bottom. There are two turrets, of $5\frac{1}{2}$-inch armour and 22 inches teak; each turret is to contain two 12-ton guns of large calibre, that will send forth shot of 300 lbs. weight.

Let us now collect into one view several particulars concerning these thirty iron-clads; taking the timber-built ships first, and then the iron-built, and arranging each group in the order of tonnage. The figures in the table are taken from the *Iron-clad Fleet of England*, published by James Reynolds, 174 Strand (Nov. 10, 1865). One in the list, the *Waterwitch*, we shall presently notice as a *nautilus* or *turbine* steamer.

WOOD.

	Tonnage.	Horse-power.	Length.	Breadth.	No. of Guns.	Inches of Armour.	Inches of Backing.
Caledonia	4125	1000	273	59	24	4½	29½
Royal Alfred	4068	800	273	59	18	6–4½	29½
Lord Clyde	4067	1000	280	59	24	6–4½	31½
Lord Warden	4080	1000	280	59	20	6–4½	31½
Royal Oak	4056	800	273	58	24	4½	29½
Ocean	4047	1000	273	58	24	4½	29½
Prince Consort	4045	1000	273	58	24	4½	29½
Royal Sovereign	3765	800	241	62	5	5½	36
Zealous	3716	800	252	59	20	4½	30½
Pallas	2372	600	225	50	8	4½	22
Favourite	2094	400	225	47	10	4½	22
Research	1253	200	195	38	4	4½	19
Enterprise	993	160	180	36	4	4½	19½

IRON.

	Tonnage.	Horse-power.	Length.	Breadth.	No. of Guns.	Inches of Armour.	Inches of Backing.
Minotaur	6621	1350	400	59	26	5½	10
Agincourt	6621	1350	400	59	26	5½	10
Northumberland	6621	1350	400	59	26	5½	10
Warrior	6109	1250	380	58	32	4½	18
Achilles	6121	1250	380	58	26	4½	18
Black Prince	6109	1250	380	58	32	4½	18
Bellerophon	4270	1000	300	56	14	6	10
Hector	4089	800	280	56	18	4½	18
Valiant	4063	800	280	56	18	4½	18
Defence	3720	600	280	54	16	4½	18
Resistance	3710	600	280	54	16	4½	18
Prince Albert	2529	500	240	48	4	4½	18
Scorpion	1833	350	224	42	4	4½–3	9
Wyvern	1899	350	224	42	4	4½–3	9
Waterwitch	778	160	162	32	2	4½	10
Vixen	754	160	160	32	2	4½	10
Viper	737	160	160	32	2	4½	10

FLOATING BATTERIES NOW EFFECTIVE.	Tonnage.	Horse-power.	Length.	Breadth.	No. of Guns.	Inches of Armour.
Wood—						
Thunder	1469	150	172	44	14	4½
Iron—						
Erebus	1954	200	187	48	16	4½
Terror	1971	200	186	49	16	4½
Thunderbolt	1973	200	187	48	16	4½
IRON SHIPS NOW BUILDING.						
Hercules	5226	1200	325	59	12	8
Monarch	5100	1100	330	57	6	6
Captain	4272	900	320	53	6	6
Penelope	2997	600	260	50	10	6

(The greatest care has been taken to secure, as far as possible, thorough accuracy in the above and the following figures.)

The number of guns may easily be changed, even after the ship is built, by a little re-arrangement. The *Royal Sovereign*, the *Prince Albert*, the *Scorpion*, *Wyvern*, *Monarch*, and *Captain*, are exceptionally remarkable for the vast size compared with the small number of guns. The first two are turret-ships. The immense thickness of timber backing in the wood ships, generally about 30 inches, is the timber hull of the ship itself. The timber backing, in most cases either 18 inches or 10 inches in thickness, has an iron skin within the timber, which helps to increase the total thickness of metal. How much these formidable vessels have cost the nation no one can yet say, not even the Admiralty. What is really known is, that the *Minotaur*, *Agincourt*, and *Northumberland* cannot cost less than £450,000 each; the *Warrior*, *Achilles*, and *Black Prince* £360,000 each; the *Bellerophon*, £400,000; the *Hector*, *Defence*, *Valiant*, and *Resistance*, £300,000 each—more than three millions sterling for eleven ships; but they will cost much more than this before they are in full fighting trim.

There are other mighty armour-plated ships building, amongst which may be cited the *Monarch*, an experimentary turret-ship, and intended to aid in solving the important problem regarding that class of vessel; another, the *Captain*, also a turret, is being built at Birkenhead; while the *Penelope*, a double-screw iron-clad, is on the stocks at Pembroke. For one of these forthcoming ships armour as much as 8 inches thick is intended; targets made of these plates have borne 8-inch round shot at a distance of only 30 feet.

Mr Scott Russell stated, in a paper read before a Scientific Institution in 1865, that a solid steel shot of 9 inches diameter, weighing 100 lbs., and requiring a 12-ton rifled gun to propel it, would require a 5-inch armour-plate to resist it; and that if the diameter of the shot were increased to 11, 13, or 15 inches, the weight to 180 lbs., 280 lbs., and 450 lbs., and the weight of the gun to 18, 24, and 38 tons, the armour to resist such shot ought to be 6, 7, and 8 inches thickness respectively. But the kind of gun, the shape of shot, and the distance of firing would all have to be taken into account, before these figures could be relied on. Nay, even the mode of making the shot itself is now known to be fraught with most momentous consequences; seeing that Major Palliser's chilled-iron shot (iron hardened into a kind of steel at the surface by a peculiar mode of cooling) have shewn such marvellous penetrating effects on massive slabs of iron backed by enormous thicknesses of timber, that the theoretical superiority of guns over armour, or of armour over guns, is left in as much doubt as ever.

Many of our iron-clads made a cruise in the Channel in October 1866, to test the speed and sea-worthiness of various forms of construction. One of the facts ascertained was, that low-hulled turret-ships are very wet and comfortless, being liable to have the decks swept from stem to stern by ocean waves.

§ XVI. FOREIGN IRON-CLAD NAVIES.

It behoves England clearly to know what progress foreign nations are making in their armour-plated fleets; besides the scientific interest of the subject itself.

France.—Our Gallic neighbours build their own iron-clads. In 1865 France was credited with no less than 36 built and 9 building. Our Admiralty assert that the British armour-plated fleet will be far more powerful and effective than that of France, ship for ship; but the French, on their side, claim certain advantages in construction which have not been so much studied in England. Experience alone can test these problems. Some naval critics have even ventured upon prediction, and assert that France in 1867 will have a superiority over England, in possessing 39 iron-clads with 720 protected guns (i. e., with the port-holes pierced in the armour), against England's 33 iron-clads with only 520 protected guns. Doctors *will* differ; and here one set of doctors say nothing concerning the relative sizes either of the ships or the guns.

Russia.—The Czar has a few iron-clads, and others building. One of them, the *Pervenetz*, built by the Thames Company in 1865, is a 30-gun ram, with a rhinoceros-shaped snout; the sides slope in greatly at the top, and are armed from stem to stern with 4½-inch iron and 9-inch backing; 2812 tons register and 300 horse-power; the guns comprise 28 68-pounders and 2 very large rifle pivot-guns. Other armour-plated ships of larger size are being built for Russia.

Prussia.—The iron-clad fleet of the rapidly-rising kingdom of Prussia is hardly yet in existence; though there are very ambitious plans in reference to it, especially since the wonderful results of the war with Austria, Saxony, Hanover, &c., in June and July 1866.

Denmark.—This small Scandinavian kingdom, just before her Schleswig-Holstein troubles began, ordered two iron-clads to be built for her on the Clyde. One, the *Rolfe Krake*, is a gun-boat of 1200 tons; $4\frac{1}{2}$-inch armour; two turrets, each containing two 68-pounders. This was the first European iron-clad actually engaged in war; it was hit a hundred and fifty times by shot from Prussian batteries in 1864, without much injury. Another, a 40-gun frigate of 3500 tons, was finished at Glasgow in 1864; it was the first iron-clad launched with the armour on. The ram is at the water-level, there being a difference of opinion among ship-builders whether it should be at or below that level. Denmark has other iron-clads in progress.

Austria.—The disjointed Austrian Empire, though sadly injured by the recent war, is ahead of Prussia in the matter of iron-clads; she has seven or eight; one of them, the *Kaiser Max*, is a wooden vessel plated with 5-inch armour, and carrying 31 guns of moderate calibre.

Turkey.—The Sultan, like the Czar and the Kaiser, is alive to the potency of armour-plated ships. He ordered four iron-clads at one time—three to be built by Napier of Glasgow, and one by the Thames Company. They are of 4200 tons, 900 horse-power, 300 feet long, 56 broad; armed with ten 110-pounder Armstrongs, and a gigantic 300-pounder at the bows. One of them, the *Mahmoud*, suffered greatly in her voyage out from Glasgow to Constantinople in 1865; another, the *Abdul Aziz*, was launched at Glasgow in January 1866. There is something still more vast, an iron-clad of 7000 tons, in progress.

Italy.—The young kingdom of Italy counts upon having twelve or fourteen iron-clads in her navy. One of them, the *Affondatore*, was launched at the Thames Company's works in 1865, and went to the bottom shortly after the battle of Lissa: it is a cupola or turret frigate of 2300 tons and 700 horse-power; armour-plates varying from 4 to 5 inches; two turrets, of $5\frac{1}{2}$-inch iron, each containing a 10-ton gun; and a rifle-tower or steering-house of equal strength; the iron masts are peculiar in being made to serve as ventilators to the hull of

the ship. The discomfiture of Italian iron-clads by Austrian ships in the Adriatic, in July 1866, raised questions which naval men will long continue to discuss; and it is evident that the real fighting capabilities of armour-plated ships will not be determined until after a long series of sanguinary wars.

Spain.—This country, which for many years has played but a small part in European politics, is causing iron-clads to be built in England. One, the *Victoria*, was launched by the Thames Company in 1865; it is a 30-gun frigate of 4860 tons and 1000 horse-power. The first iron-clad ever seen in the Pacific belonged to Spain; it was the *Numancia;* a ram of 1000 horse-power, carrying a broadside of 68-pounders; it was sent out to take part in the demonstration against Peru in 1865; but it earned the character of being a very bad sea-boat, with the port-holes only a little way above the level of the water.

United States.—The republic has passed through so tremendous an ordeal, and is undergoing reconstruction in so many ways, that it is not safe to make definite statements as to her navy. The greatest interest hitherto bestowed upon iron-clads in actual service was in the case of the American *Merrimac* and *Monitor.* The *Merrimac* had been a 40-gun steam-frigate of the ordinary kind, belonging to the United States navy; but when she fell into the hands of the Confederates, they altered her to an iron-clad. The hull was cut down to within three feet of the water; it was plated with iron rails at midships, and with steel at the bow and stern; there were 10 guns of 11-inch bore, a sharp ram, and a bomb-proof house on the gun-deck; there were no masts, and scarcely any surface for an enemy to fire at. The *Monitor,* built by the Federals on a new plan, was a turret-battery, by Ericsson. Hardly anything was visible but a turret 22 feet diameter by 9 feet high, to carry two enormous guns. There were two ports on one side of the turret, through which the two guns were thrust out parallel; the turret revolved; and the gunners took aim by revolving the turret and the guns together, there being easily-worked mechanism for this purpose. The deck is so near to the level of the water, that all the rooms for officers, crew, and

stores are necessarily below water, rendering light and ventilation difficult things to manage. In actual service, the *Merrimac* destroyed almost every ship she attacked; but in turn she was beaten by the *Monitor*. A knotty problem certainly remains to be solved. A *Monitor* may hit a *Warrior* in many places by successive discharges from two great guns; but a *Warrior* has got nothing to aim at in a *Monitor* except a sort of Martello tower of five or six inch iron, whose rounded surface would be likely to divert a shot. The solution of these problems will be a dreadful one, whenever it occurs. The Federals attacked Charleston with a regular fleet of iron-clad monitors in April 1863; some of them had only one gun each, but a gun of most formidable size—15-inch calibre. These monitors are so much cheaper and so much more quickly built than the vast armour-plated ships of England, that there may be fifty or sixty of them built without very heavily straining the resources of the United States. One of them, the *Miantonomah*, which attracted a good deal of attention at Southampton in the summer of 1866, is 268 feet long, 59 feet broad, 1600 tons burden, with a deck only $3\frac{1}{2}$ feet above the water; two turrets 8 feet high, 23 feet in diameter, and ·11 inches thick. Each turret carries two smooth-bore Dahlgren guns, hurling either 480-pounder spherical shot or 360-pounder shells of 15-inch diameter. Whether any armour-plate in the world could resist these tremendous projectiles, the future must tell.

§ XVII. NOVELTIES AND ODDITIES IN SHIP-BUILDING.

MIGHTY as is our steam navy, especially in relation to the vast armour-plated vessels, and still more mighty as it is likely to be in future years, there is nevertheless far greater importance to be attached to our mercantile marine. Taking all the ports

in the British Islands, and the merchant ships of all nations with which we trade, the commercial history of the year 1865 informed us that no less than 44,000 ships laden with cargoes entered our ports from foreign countries; that 48,000 ships laden with cargoes left our ports for foreign countries (there being more vessels enter than leave our ports empty or in ballast); and that 148,000 ships carried cargoes from one British port to another—240,000 cargoes in all!

This commercial aspect of shipping matters, however, extends beyond the scope of the present volume. We may more suitably conclude the chapter with a brief notice of a few specimens of the ship-builders' art, which are either important for their advantages, or novel and out-of-the-way in some of their features.

Steel Ships.—This designation tends to convey to the mind an idea of vessels enormously expensive, such as services of a very exceptional character could alone justify. And such would really be the case if steel were made by the methods alone used a few years ago. But there are now new processes. By the inventions of Bessemer, Clay, and others, steel can be made at a much lower cost than formerly. It is true that for very choice purposes, steel of the old kind is still necessary; but for intermediate kinds the new processes are admirably suited. One advantage is, that steel of any degree can be produced between iron and steel; that is, iron can be steeled or steelified little or much, according to the purposes for which it is to be employed. 'Steel iron,' and 'half-steel,' and 'semi-steel' are now admitted designations. It hence follows that, though a steel ship may be built, the metal need not be such complete steel as good cutlery, or files, or saws are made of. A ship with steel plates instead of iron plates, and steel ribs instead of iron ribs, can be of equal strength with less thickness of metal, and therefore can be more buoyant and swift in the water, irrespective of being more durable. It may therefore be worth a ship-owner's while to spend more for the metal in the first instance, as a means of obtaining a vessel better in speed and durability. Every year such ships are now being more and more adopted; and the data

are gradually being obtained for estimating exactly the comparative merits of the two kinds of construction. The mode of building up and fastening is nearly the same for steel ships as for iron.

The *Cigar Ship* is so named from its extraordinary shape, which would exactly resemble a cigar if the latter were pointed at *both* ends. Messrs Winans, the inventors and proprietors, have already built three on this model—one at Baltimore, 230 feet long; one at St Petersburg, of smaller size; and one at Havre, the smallest of the three. A larger specimen than any of these, the steam-yacht *Winans*, was launched at Hepworth's yard, Millwall, in February 1866. It is 256 feet long by only 16 wide, the cross section being almost exactly a circle. At 18 feet from each end is a screw-propeller of six blades. The portion of eighteen feet beyond the propeller revolves with it, and therefore forms a kind of nut for the screw. There are two rudders, one near each end; so that the vessel can travel either end foremost. The deck is 130 feet long by $10\frac{1}{2}$ broad, built upon the upper curvature of the cigar-shaped mass; and above the deck project two short funnels. The casing below water is made of $\frac{5}{8}$ Lowmoor iron; above water, of $\frac{5}{16}$ steel. The framing within this casing consists of iron circular girders, in conjunction with 20 water-tight partitions. The screw-shaft, made of steel, varies from 7 to 15 inches in thickness, in different parts of its length. There are three engines, which are said to be capable of working up to 2000 horse-power. The four boilers are constructed like locomotive boilers. The saloon is literally a tunnel, 25 feet long; and the smaller sitting-rooms and sleeping-berths are packed into curious nooks and curved recesses. The sleeping accommodation is for thirty persons in all—officers, visitors, and crew. There is a smoking-cabin, another tunnel 12 feet long. The two anchors are simply solid cylinders a ton-weight each, expected to steady the ship by their weight, without actually biting into the ground; there are very curious recesses in the bottom of the ship, into which these cylinders fit like stoppers when not in use. The designers appear to have

peculiar views as to the advantages of such an utterly novel mode of construction; but nothing less than repeated voyages, under many variations of sea and wind, will apply a practical test.

Jointed Steamers.—A steamer has been constructed called the *Connector*, bearing a little analogy to a railway goods train. In such a train one or more of the hindermost trucks can be unhooked and detached at any station, and the rest go on without unpacking the cargo. A similar object is borne in view in the *Connector*. It consists of several iron vessels or barges, linked end to end, the last section containing the engine and paddles. When employed in the coasting trade, the hindermost vessel can be detached and left at any port for unloading, while the rest go on without delay; on the return-voyage it can be picked up again and hooked on. The theory is certainly an ingenious one, in regard to saving of time. The chief point which has to be determined is, whether the separate vessels, the joints of the tail, would be torn asunder in a heavy sea. There is a principle somewhat analogous to this adopted in the steam flotilla now employed on the Indus from Moultan to Kurrachee.

Floating Bridges.—These are steamers which ply as ferry-boats across harbours and estuaries. There are two chains extending from shore to shore, but hanging down so as to be out of the way of passing ships. Certain revolving wheels in the steamer catch in the links of these chains; and as the vessel cannot pull the chains along, the chains pull the vessel along. This course is adopted as a means of compelling the steamer to keep a straight line to and fro, without being affected by winds, tides, or currents. The steamer is generally broad and flat enough to accommodate coaches and carts, with their horses and burdens undisturbed; and by means of hinged platforms lowered at the two ends, the horses and vehicles can embark and disembark with facility. Some of them receive railway trains, on rails brought up exactly on a line with those of land railways at the two ends. Such floating bridges are now used across estuaries in various parts of England.

The Turbine or *Nautilus.*—In this new invention, by Mr Ruthven, paddle and screw are alike dispensed with. Numerous small holes in the bottom, near the centre of the ship, allow water to flow into a water-tight compartment. A *turbine*, or water-wheel of peculiar construction, made to rotate by a steam-engine, and immersed in this admitted water, drives it out at two nozzles parallel to the keel, in the direction of the stern. The reaction thus produced propels the vessel in the opposite direction. By using two nozzles, or only one, the inventor hopes to turn the ship more quickly, and in a shorter length, than has ever yet been done; in fact, the nozzles, in emergency, might almost serve the place of the steering apparatus. The idea itself is very old, but the mode of applying it is novel. A recently-built iron-clad gun-boat, the *Waterwitch*, is likely to furnish a valuable test to the merits of the invention. Some of the practical officials at Portsmouth having strongly recommended a government trial of the system, the Admiralty commissioned the Thames Company to build a small iron-clad, the machinery to be constructed by Messrs Dudgeon. This vessel, the *Waterwitch*, is of 778 tons; 162 feet long, 62 feet wide, and 14 deep; clad with $4\frac{1}{2}$-inch armour plates, backed by 10 inches of teak. There is a rudder at each end, to enable it to steer either ahead or astern. The bottom, near the centre, is pierced with a great number of small holes, which admit the entrance of water into a kind of shallow iron box. The water thus admitted can only find exit by certain channels into a beautifully-made metallic cylinder or case 10 feet in diameter. In this cylinder, on a vertical axis, revolves the turbine or water-wheel, which weighs 8 tons, and is divided by partitions into as many compartments. When this turbine is made to rotate rapidly, by the action of a steam-engine of 160 horse-power, it draws in water from the tank or box beneath into the cylinder, and then drives it out of the cylinder sideways by virtue of irresistible centrifugal force. The water passes out by two propulsion-tubes of large diameter, which extend through the sides of the ship; at their outer extremity they are terminated by two brass nozzles, 24 by 18

inches in diameter, bent backwards towards the stern. The violent rushing out of streams of water through these nozzles, acting against the water of the sea, drives the ship forward. The first trial of the *Waterwitch* (October 19, 1866) was very favourable as regards speed. Other tests of excellence were then to be gradually applied.

Unsinkable Ships.—Mr Lungley has invented what he calls *unsinkable* and *incombustible* ships. The spaces between the decks are thoroughly separated from each other, each being water-tight even if the deck over it were filled with water. There are not even stairs from the one to the other, each having an iron-bound well staircase up to the open air, without communicating with any intermediate deck or space. The theory is, that if the whole length of the ship were filled with water between any two decks, it would still not sink, because the hold or the other spaces would be water-tight and full of air. If any part were to take fire, the flames might be quenched by quickly filling the whole of that space with water, without overweighting the vessel. In this sense it would be both unsinkable and incombustible. The engine-room is enclosed in four solid walls of iron, to isolate it from the rest of the fabric. A ship so large as 1000 tons has been built on this principle; but we are not aware that the unsinkability and incombustibility have yet been put to a test arising really out of the exigencies of actual service.

Double-screw Ships.—This principle has been applied by Messrs Dudgeon to certain ships with great success. Two screw-propellers are placed one on each side of the keel. It is conceived that by using one or both screws, or one moving faster than the other, a ship can be rendered more manageable than if there is only one screw in a line with the keel. A double-screw called the *Far East* was launched at Cubitt Town in 1863 for the China trade; it is of 1720 tons, and has two screws of 8 feet diameter and 16 feet pitch. Another, the *Ruahine*, has been placed on the Panama and New Zealand route; it is 265 feet long, 34 wide, 1500 tons, and 350 horse-power; and will accommodate 200 passengers besides the crew. A beginning is also being made

in the application of the principle to war-steamers, the gun-boats *Viper* and *Vixen*, for example. The two screws can be worked together or separate, and in similar or in opposite directions, which facilitates, in a notable degree, the turning of the ship in a short space of time and a small amount of sea-room.

Twin-steamers.—We have already noticed that, in the early days of steam navigation, twin-steamers were sometimes tried, consisting of two boats side by side, with a paddle-wheel between them. The plan has been occasionally adopted in an altered form; a broad, double-stemmed, double-sterned ship, with a cell or hole in the middle to receive the paddle-wheel. In one of the smallest and earliest kinds, the boiler was in one boat and the engine in the other; but in later specimens, the machinery has been distributed around the paddles in various ways. It is curious that, about the year 1830, there was something very like a *double-cigar ship* in the Clyde, each half of a twin-steamer having nearly the shape of a cigar.

Canoes for Tourists: the Rob Roy.—Considerable attention has lately been directed to the prosecution of pleasure-voyages in canoes, by tourists who are prepared to 'rough it' under circumstances of singularly little personal accommodation. In rude and semi-barbarous countries, the natives are wont to scoop out the trunk of a tree and convert it into a canoe, to be paddled along rivers or near coasts; and from that as a model has proceeded the canoe now constructed by boat-builders in various countries, having a nearly water-tight deck or covering. Such a canoe is occasionally seen on the Thames and other English rivers. Mr Macgregor, in 1865, caused a canoe to be built on a plan determined by himself; and with this canoe, called the *Rob Roy*, he made voyages amounting to a thousand miles altogether, in the summer and autumn of that year, on the rivers and lakes of Germany, Austria, Switzerland, and France. The canoe was so narrow and shallow that a single occupant had to take his seat very carefully to avoid upsetting the frail bark. The deck had an oval hole in the middle, in which the navigator sat; and a waterproof apron was

closed around the hole, after he was seated, in such a way as to shield the lower part of his person from wet; but there was no shelter for head or body, and no change of posture for feet or legs. The tourist paddled along, with his face in the direction in which he was going (a more pleasant arrangement than that usually adopted in the rowing of a boat); and his stores, provisions, and spare clothing were brought down to the lowest possible weight and bulk, in order that the slender fabric might not be swamped or rendered unmanageable by too much burden. A lively narrative, which Mr Macgregor published, giving an account of his thousand miles of travelling, excited so much interest that a 'Canoe Club' was soon formed; and the members of the club organised various canoe-voyages for the year 1866, in the rivers and lakes of Norway, Sweden, &c.

Ocean Boats: the Red, White, and Blue.—The successful crossing of the Atlantic by the *Red, White, and Blue*, a mere boat in all its dimensions, has shewn that buoyancy can be maintained in spite of the winds and waves of a stormy ocean. It was a freak, an adventure, like the climbing of the Matterhorn or the Jungfrau; but it was not without its usefulness as an illustration of navigation. This tiny vessel was built by Mr Ingersoll, at New York, for Mr Hudson of the same city. It is in principle a metallic life-boat of only 2½ tons burden: length, 26 feet; breadth, 6 feet; depth of hold, 2 feet 8 inches; depth from deck to keel, 3 feet. She is sharp at both ends; the interior is divided into water-tight compartments both lengthwise and breadthwise; and there are safety-valves which will cause the boat to free herself of water in a few minutes. Small as it is, the boat is ship-rigged—bowsprit, jib-boom, flying-jib-boom, fore-mast, top-mast, topgallant-mast, royal-mast, main-mast, and mizzen-mast, with top-masts and topgallant-masts to carry them up to the proper height, spanker-boom, fore lower yard, main lower yard, top-sail yards, topgallant yards, royal yards, cross-jack yard, top-mast stunsail-booms, and topgallant stunsail-booms—all duly proportioned in size to the miniature ship. Then the spreading canvas includes staysails, jibs, flying-jibs, courses, top-sails, top-

gallant-sails, royals, spankers, stunsails, and trysails. She is decked over, but has a cockpit for the steersman around the mizzen-mast. She was launched June 21, 1866; and then fitted with spars and rigging. A voyage across the Atlantic being resolved upon, the voyagers took in a store of water, bread, tea, coffee, butter, herrings, milk, smoked beef, cheese, pickles, mustard, pepper, salt, sauce, brandy, whisky, bitters, and other provisions; together with nautical instruments, medicines, &c. as much as the boat could take with safety. The voyage was made by two men and a dog. Mr Hudson was captain; Mr Fitch was mate or assistant; and the dog 'Fanny' was a very unwilling participant in the voyage. They set sail on July 9; they reached Margate on August 16: and during the voyage of thirty-eight days, they found their resolution and powers of endurance sorely tried. The two men kept watch and watch, turn and turn about. They were nearly always wet, and were seldom able to light their kerosene stove to warm liquids or food. The cockpit or hole was a hard place to sit in, but there was nothing better. When they got beyond the region of the Gulf Stream, they experienced much cold weather. The adventurous master and mate reached England safely; but the poor dog Fanny succumbed to the troubles she had undergone.

Annals of Steamers from 1815 to 1866.

We now present half a century of jottings relating to the rapid progress of steam-navigation, as illustrated by a few facts in each of the principal developments of the system, warlike and commercial.

1815. First steamer belonging to any government, United States (the *Fulton*).
1816. Steam-trade began on the Thames.—Steamers crossed the Channel to Calais and Flushing.
1817. Steam-traffic on many continental rivers.—United States had steamers as large as 450 tons plying on the great rivers.
1818. About 60 steamers plying on English and Scotch rivers.—Steam-traffic established between Scotland and Ireland.
1819. The finest steamers yet seen in England were placed upon the Holyhead and Dublin route.
1820. Fifty-seven steamers of 9000 tons aggregate built down to this time in the British dominions.—Thirty-four plying in the United Kingdom.
1821. The Irish and French mails transferred from sailing-packets to steamers.
1822. First steamer, *Monkey*, belonging to the British government.
1823. By this time there were 240 voyages made in the year by steamers between English and foreign ports, besides 1100 coasting-voyages.
1824. Aggregate of British steamers now reached 174, of 24,000 tons—29 built this year.—The *Columbus*, 300 feet long, steamed from the St Lawrence to England; failed through weakness of build.
1825. The *Enterprise* made the first steam voyage from England to India, round the Cape of Good Hope.—American steamer *Trenton*, with boilers placed on the outside sponsons.
1826. Steamer *London Engineer*, with one paddle in the middle, for canal traction.
1827. Steam-ship building commenced at Calcutta.
1828. More than a thousand steam voyages made to or from British ports and as many as 12,000 coasting voyages.
1829. Government began building six 50-gun war-steamers.—Dutch steamer 250 feet long, with four masts—a failure.
1830. Down to this time, the average burden of all British steamers, both for river and sea, did not exceed 120 tons.

1831. Captain Chesney descended the Euphrates 980 miles in a boat, to explore new steam-route to India.

1832. Parliament ordered an inquiry into schemes for an India mail steam-route.

1833. Nearly 1500 steam voyages made to and from British and foreign ports, and 18,000 coasting voyages.

1834. About 90 steamers added to the list of British shipping this year.

1835. First company formed for Atlantic steaming.—Establishment of mail-steamers to Isthmus of Suez.

1836. The *Archimedes* yacht introduced Smith's screw-propeller to public notice.—Captain Chesney navigated the Euphrates in an iron steamer.

1837. First conveyance of India mail by the Overland route.—Ericsson's screw-propeller introduced.

1838. Rival voyages of *Great Western* and *Sirius* across the Atlantic.—Monthly Overland mail organised.—Passenger steamer of 860 tons on the Mississippi.

1839. The wave-principle in ship-building established in the *Fire King*.—Three hundred and fifty-six ships-of-the-line in European navies (no steamers).

1840. Cunard line of Atlantic steamers established.—Down to this date there had been 770 steamers built in the British dominions.—Screw-propellers began to be adopted for merchant-steamers.

1841. First mail-steamer to West Indies.—Admiralty ordered the first screw war-vessel, *Rattler*.—Iron ships came much into use.

1842. Suez and Calcutta steam-route undertaken for the East India Company by the Peninsular and Oriental Company.—First suggestion (not adopted) for an iron-clad.

1843. Admiralty began to build iron ships.—*Great Britain* launched at Bristol.—Southampton established as the port of departure for Oriental and West India mail-steamers.

1844. First war-screw built in United States.—Steam-reserve formed in British navy.

1845. War screw-steamers rapidly superseding sail; 23 in the navy.—First voyage of *Great Britain* across Atlantic.—First regular steam-mail to China.

1846. First mail-steamers in Pacific.—Auxiliary screws adopted in navy.—*Great Britain* stranded for a whole year on the Irish coast.

1847. The *Sarah Sands*, auxiliary iron-screw, established the advantage of the combined system in merchant steaming.

1848. An estimate that all cargo-laden ships and steamers entering British ports were worth, ship and cargo included, about £5000 each on an average.—Forty-five government screw war-ships built and in hand.

1849. Maximum size of ocean mail-steamers 2000 tons.—1044 wood and 66 iron merchant-steamers in British dominions.—Auxiliary screw attached to Arctic ships.

1850. Collins line of steamers began to ply on Atlantic, 2900 tons each.—2000 steamers navigating rivers and lakes of America.

1851. First mail-steamer to the Cape.—4400 ships entered Liverpool alone.—Of all British and colonial steamers, nearly half under 50 tons.

1852. Launch of *Duke of Wellington*, the first 131-gun screw war-steamer.—American liner *Washington*, New York to Liverpool in 13½ days.—First steam-mail from England to Australia, *viâ* the Cape.

1853. The *Great Eastern* begun.—First screw with two fighting decks, *Agamemnon*, 91 guns.—First steam-mail to Australia *viâ* Suez.

1854. Baltic fleet had only 16 sailing vessels, against 38 screw and 41 paddle steamers.—First circumnavigation of the globe by a steamer.

1855. First Passenger Act passed, to regulate ocean steamers and sailing ships.—107 paddle and 78 screw steamers in British navy.

1856. The *Persia*, the finest merchant steamer then afloat, added to the Cunard fleet.

1857. Failure of attempt to launch *Great Eastern.*—The *Niagara*, steam-corvette of 12 guns, as large as old line-of-battle ships.

1858. French screw troop-ship launched, to accommodate 2500 soldiers.—*Great Eastern* launched.—100 screw-steamers in British navy.

1859. The navies of the European nations and United States comprised about 2600 ships, of which more than half were steamers.

1860. First French iron-clad, *La Gloire.*—Steam-frigates of 26 guns larger than 50-gun frigates of 1839.—*Great Eastern* made her first voyage.

1861. British iron-clad navy commenced; launch of the *Warrior.*—Paddles nearly abandoned in navy, except for small ships.—*Scotia* Cunard steamer launched; largest merchant ship afloat except *Great Eastern.*

1862. The *Royal Oak*, first *wooden* iron-clad in navy.—Coles's cupola-ships introduced.—The *Merrimac* and *Monitor* battle in America.

1863. First naval attack upon fortresses by iron-clads, at Charleston.—Launch of the *Minotaur* iron-clad.

1864. Fight of the *Alabama* and *Kearsage.*—British mercantile marine comprised 26,142 sailing vessels and 2490 steamers.

1865. Launch of *Agincourt* iron-clad, largest then afloat.—First mail-steam route organised across the Pacific.

1866. *Great Eastern* successfully employed in laying and raising telegraphic cables.—Iron-clads rapidly superseding other vessels of war.—Ocean voyage of the *Red, White, and Blue* boat.

CHAPTER III.

TELEGRAPHS.

§ I. THE OLD MODES OF TELEGRAPHING.

HOW to bring the distant near, to convey a man's thoughts or wishes, commands or fears, instantly to one who is far beyond speaking-distance, has been an object of solicitude from very early times. It is the topmost stone of the pyramid, whereof the base is travelling, and the middle portion letter-carrying. It is the travelling of *thought*—invisible, intangible, inaudible. Of course, the earlier attempts at this achievement were clumsy enough. Although flags, lanterns, rockets, blue-lights, beacon-fires, gun-firing, trumpet-blowing, drum-beating, and gong-beating may be made use of as *semaphores* (sign-bearers), the name of *telegraph* (distant writing) has usually been assigned to such contrivances as may be applied to a vocabulary of preconcerted words. To arrange two or more blazing torches in varying positions; to place them so that screens might cover one or more of them alternately; to write letters on an upright board, and shew any one of them at a time by some mechanical arrangement; to denote the letters of the alphabet by alternately raising and lowering three torches; to denote letters by the longer or shorter obscuration of one single torch; to attach two lights to long poles, and turn them about in various ways; to

cut letter-holes in the ends of casks, and put lights within the casks—all were contrivances which ingenious men devised, with more or less success, for sending short signals to distant places.

The establishment of a telegraph necessarily involves a certain degree of civilisation—there must be fixed habits and steady policy; and we cannot better appreciate the advantages of the present system than by contrasting it with the past. To distinguish objects afar off there must be the possibility of seeing at a distance; and thus the study of optics and the invention of telescopes and reflectors would naturally suggest new applications of utility. The Marquis of Worcester alludes to a telegraph in his famous *Century of Inventions*. After him we may place Robert Hooke, who, in 1684, presented a paper to the Royal Society, 'Shewing a way how to communicate one's mind at great distances.' He had conceived the project long before; but the then recent siege of Vienna by the Turks had caused him 'to take up again with his plan for discoursing at a distance, not by sound, but by sight.' The principle involved the use of telescopes, less simple and ingenious than that which afterwards came into use, but worthy of notice. He contrived an elevated framework, supporting a panel or screen, behind which were suspended a number of deal boards cut into the shape of letters. When a message was to be sent, the letters were drawn one by one from behind the screen, by means of pulleys, and exhibited in an open part of the framework, where they could be seen from a distance; there were thus as many separate movements as there were letters in the message to be conveyed.

Amontons appears to have been the first to render a telegraph available for practical purposes about 1690, by 'a means which,' as recorded by Fontenelle, 'he invented to make known all that was wished to a very great distance—for example, from Paris to Rome—in a very short time, three or four hours, and even without the news becoming known in all the intervening space. This proposition, so paradoxical and chimerical in appearance, was executed over a small extent of country. The secret consisted in placing in several consecutive stations persons who, by

means of telescopes, having perceived certain signals at the preceding station, transmitted them to the next, and so on in succession; and these different signals were so many letters of our alphabet, of which the key was known only at Paris and Rome. The greatest reach of the telescopes determined the distance of the stations, of which the number was to be the fewest possible; and as the second station made signals to the third as fast as they were received from the first, the news was carried from Paris to Rome in almost as little time as it took to form the signals at Paris.' Another projector, named Marcel, followed with no better fortune than his predecessor. Wearied with attendance on a dilatory government, he broke his machine and burned his drawings, and died without revealing his secret. Next, Linguet, who had been for some years a prisoner in the Bastile, claimed the merit of the invention, and offered to construct a telegraph in exchange for his liberty. History is silent as to his offer being accepted. In course of time a private attempt was made: Monsieur Dupuis of Belleville constructed a telegraph, by means of which he communicated with his friend Fortin, who lived a few leagues off at Bayeux. Meanwhile, attention being drawn to the subject in other quarters, the time for realising a speedy-transmission project was at hand.

It came at last with its man. Claude Chappe, when a youth in a religious establishment at Angers, had contrived an apparatus, a post bearing a revolving beam and circulatory arms, with which he conveyed signals to three of his brothers who were at a school about half a league distant, and who read them off with a telescope. Keeping the idea in view for several years, he eventually laid his plans before the legislature in 1792, assuring them that 'the speed of the correspondence would be such, that the legislative body would be able to send their orders to the frontiers, and receive an answer back, during the continuance of a single sitting.' After much vexatious delay, the authorities approved the plan; and Chappe, with the title of Ingénieur Télégraphe, was appointed to erect a telegraph from Paris to Lille. The line, with its apparatus (a combination of a

pole, a beam, movable arms, and ropes), which admitted the formation of 192 different signals, was completed in two years. Its first announcement was a victory. On the last day of November 1794, Carnot entered the Assembly with the news, 'Condé is given up to the Republic! The surrender took place this morning at six.' The Chamber voted that 'the Army of the North had deserved well of the country,' and caused their approval to be sent to head-quarters; and before the legislators broke up, they were informed that their orders had been transmitted to Lille, and the receipt acknowledged. This successful result led to the immediate formation of other lines which radiated from Paris to all the frontiers of the kingdom. The signals (depending on varying positions of the beam and arms) were conveyed with great rapidity; and to avoid confusion, the movable arms on the right of the central post were kept exclusively for government messages, those on the left being employed in the service of the line. Thus, accidents or delays could be reported without detriment to the official dispatch; and the government were enabled to use a cipher or secret alphabet of their own. From Paris to Calais, 152 miles, there were thirty-three stations, and a message could be sent from one extremity to the other in three minutes; to Strasburg, 255 miles and forty-four stations, in six and a half minutes; to Toulon, 317 miles and one hundred stations, in twenty minutes. The longest lines were to Brest and Bayonne—the former 325 miles, the latter 425; and altogether there were 519 stations, the annual cost of which amounted to £40,000. The last of the brothers Chappe was in office until 1830, when the July revolution deprived him of his post and its emoluments.

The new mode of correspondence was speedily adopted by the other governments of Europe, and numerous forms of apparatus were proposed by enterprising inventors, some of them remarkable for the infinite multiplicity of their signals. Mr Lovell Edgeworth, father of the distinguished writer, Maria Edgeworth, contrived a telegraph of four wedge-shaped boards mounted on the tops of poles, and so pivoted as to assume

any among several different positions. He thought so highly of his plan that he even pictured to himself the establishment of such a system all the way from England to India. Mr Gamble invented an apparatus of shutters to fill the openings in a window-frame, different signals being conveyed by the alternate opening and shutting of the spaces. Lord George Murray, in 1795, substituted a different arrangement of shutters; and the Admiralty so far approved of this plan as to adopt it for a telegraph between London and Dover. In 1806, by the application of a sliding shutter, Mr Davis increased the power of Murray's telegraph fourfold. Some experimenters went as far as a ten-shutter arrangement. Experience led the Admiralty, in 1816, to adopt a modification of the old movable arm system, as being on the whole more advantageous than that of shutters. The plan eventually selected was that of Sir Home Popham, in which two arms were pivoted to an upright post. It did not give a large number of signals; but the machinery for moving the arms was so simple and effective, and the angular position so easily seen at a distance, that Popham's telegraph remained in use until superseded by the wonder-worker electricity. Other schemes there were in plenty, by Macdonald, Law, Conolly, Hardy, Spencer, Spratt, and other inventors; but these we need not stop to describe.

With all its advantages, however, the Popham telegraph was an imperfect contrivance, altogether useless at night, or during fogs and gloomy weather. For three-fourths of the year, the telegraph from London to Portsmouth stood idle. One of the many oddities connected with this telegraph was the following. On an occasion when important news was expected from Spain, the Admiralty officials were discouraged by the receipt of a message—'*Wellington defeated.*' It was afterwards ascertained that the true message was, '*Wellington defeated the French at*'—Salamanca, or wherever the place may have been; but a fog checked the signal-observing after the second word.

§ II. ADOPTION OF FRICTIONAL ELECTRICITY.

A WONDROUS Mercury, a messenger with lightning speed, was now in waiting, and at the service of mankind. The days of *electro-telegraphy* were at hand, by one of the most marvellous applications of science to useful purposes that the world has ever seen.

The electric telegraph belongs to our own age, but its beginnings take us back to the age of conjecture and the dawn of philosophy. Six hundred years before the birth of Christ, Thales had observed that amber, or *elektron*, as the Greeks called it, exhibited, when rubbed, certain properties of attraction which it did not otherwise possess. Besides giving us the word in which our term *electricity* originates, the early philosophers left behind them several accounts of electrical phenomena. Aristotle, Theophrastus, Pliny, Cæsar, and Plutarch all mention them. Singular flames were sometimes seen on the tops of the masts of ships in the Mediterranean, or quivering on the heads of the wondering mariners; and on several occasions Roman troops, while on a march, had observed similar luminous appearances on the points of their lances. Coming down to a later period, we find Eustathius, in his commentaries on Homer, relating the case of Walamir, uncle of Theodoric the Goth, whose body gave out sparks; and of another individual who, on drawing off his clothes, saw flames or scintillations leap from his skin with a crackling noise. From Thales to the seventeenth century is a long period; yet, scanty as is the record of facts, it is sufficient to shew that electrical phenomena had not passed without notice. According to some theorists, iron crept about or grew within the body of the earth; and its transmission along deeply-buried tubes, provided by nature, was the cause of magnetic variation at the surface. Otto Guericke produced the first

electrical machine—a globe of sulphur made to rotate by means of a winch, while the friction of a piece of cloth held against it excited the electrical influence.

The eighteenth century came, and opened the most famous page in the history of electricity. For Guericke's ball of sulphur, Hawksbee substituted a globe of glass; while other experimentalists used straight glass tubes rubbed with the hand. Stephen Grey found that all substances might be classified as electrics and non-electrics; and, by means of packthreads more than 100 feet in length, was the first to prove that the electric impulse could be transmitted to a considerable distance. In company with his friend Wehler, he discovered also the insulating properties of glass, silk, hair, and resin, besides some other bodies. In France, Dufay and Nollet were labouring diligently at the same pursuit. By wetting a cord, they observed that Grey's experiment could be greatly extended. They sent a current through 1300 feet. To Dufay belongs the merit of discovering the two kinds of electricity, which he named *vitreous* and *resinous*, or, according to the present terminology, *positive* and *negative*. Germany next added a few facts to the growing science. A Scottish monk at Erfurt, by adopting glass cylinders, gave to the electrical machine almost its present form, and marvellous effects were produced. In 1746, the three philosophers of Leyden produced the jar which still in name perpetuates the place of its discovery.

Laying aside, however, the phenomena of shocks and sparks, the investigations which most claim our attention are those which relate to the transmission of electricity to long distances. With lengths of wire held by human hands, Nollet formed a chain more than 5000 feet long, and found that the passage of the shock through the whole number of individuals was instantaneous. The same fact was still more satisfactorily demonstrated in England by Dr Watson. He carried a wire across the Thames at Westminster Bridge, one end being in contact with a charged jar, the other held by a person on the opposite shore; a second individual was placed in communication with

the jar, and on a given signal the two dipped into the river an iron rod which they held in their hands; on which the shock travelled from one side of the stream to the other by means of the wire, and came back through the water to complete the circuit. This was an important discovery, inasmuch as it involved the principle on which depended all subsequent experiments on transmission to a distance. Watson repeated his experiments on several occasions—the last time near Shooter's Hill—with two miles of wire; and the now familiar fact that observers, however far apart, feel the shock at the same instant, then excited a degree of astonishment bordering on incredulity. Franklin's famous kite experiment, which proved the identity of lightning and electricity, may be regarded as the climax of electrical discovery in the past century. No sooner had the general nature of the new and startling phenomena become known, than the idea immediately sprang up of employing the mysterious agency in the conveyance of signals. Maunoir relates that, in 1773, Odier wrote to a lady of his acquaintance: 'I shall amuse you, perhaps, in telling you that I have in my head certain experiments by which to enter into conversation with the emperor of Mogul or of China, the English, the French, or any other people of Europe, in a way that, without inconveniencing yourself, you may intercommunicate all that you wish, at a distance of four or five thousand leagues, in less than half an hour! Will that suffice you for glory?'

Other minds were also occupied with the subject. In 1774, Lesage, a Frenchman at Geneva, published a plan for an electric telegraph. He proposed to arrange twenty-four metal wires in some insulating substance, each connected with an electrometer, from which a pith ball was suspended. On exciting the wires by means of an electrifying machine, the movements of the twenty-four balls represented the letters of the alphabet, as might have been agreed on. The project, though ingenious, was never carried into execution, and would have failed at great distances. Arthur Young, in his *Travels in France*, gives us an account of a somewhat similar contrivance, which affords

further evidence of the interest felt in the subject of electric communications. Under the date September 16, 1787, he writes: 'In the evening to Monsieur Lamond, a very ingenious and inventive mechanic. In electricity he has made a remarkable discovery. You write two or three words on paper; he takes it with him into a room, and turns a machine enclosed in a cylindrical case, at the top of which is an electrometer, a small fine pith ball; a wire connects with a similar cylinder and electrometer in a distant apartment; and his wife, by remarking the corresponding motions of the ball, writes down the words they indicate, from which it appears that he has formed an alphabet of motions. As the length of the wire makes no difference in the effect, a correspondence might be carried on at any distance: within and without a besieged town, for instance; or for a purpose much more worthy, and a thousand times more harmless—between two lovers prohibited or prevented from any better connection. Whatever the use may be, the invention is beautiful.' It was not only beautiful, it was a real electric telegraph on a small scale.

A method proposed by Reiser in Germany, in 1794, exhibited illuminated signals. Plates of glass partially covered with tinfoil were connected by wires with a machine, and sparks of light became visible on the uncovered parts of the glass when the electric current was passing. Cavallo, again, suggested in 1795 the explosion of a Leyden jar as a means of arousing the attention of the distant operator. In the following year Salva, a Spanish physician, constructed an electric telegraph, and described it in a memoir which he laid before the Academy of Sciences of Madrid. The Infant Don Antonio was so much interested in the invention, that he caused a telegraph to be erected, and turned it to practical use. Shortly afterwards a more extensive attempt was made by Betancourt, who stretched wires from Aranjuez to Madrid, a distance of forty-five miles, and conveyed his signals by the discharge of jars.

§ III. ADOPTION OF VOLTAIC ELECTRICITY.

THE telegraphs just brought under notice failed, because they were worked by *statical* or *frictional* electricity—that is, electricity obtained by friction, or from Leyden jars. This kind of electricity is remarkable for what is called its *tension*, or tendency to fly off from its conductors. It is an agent not to be depended on or held in control, and proves itself often capricious, from various causes, some of them inappreciable; among the known, damp is one of the most influential. Hence the realisation of electric telegraphs on a large scale was essentially impracticable. Signals, it is true, might have been transmitted within a building, but not for miles out of doors, in all weathers. For the further development of telegraphy, we are indebted to dynamic electricity, or electricity without tension; that is, without a tendency to abandon the conductors along which it travels. Its phenomena, when compared with those of statical electricity, are much more striking and interesting.

In the whole history of accidental discovery, there is no event more remarkable than that by which that other form of electricity, known as galvanism, was brought to light. To quote M. Arago: 'It may be proved that this immortal discovery arose in the most immediate and direct manner from a slight cold with which a Bolognese lady was attacked in 1790, for which her physician prescribed the use of frog broth.' In accordance with the medical advice, a number of frogs were prepared for stewing, and by some chance a few of them were laid on a table near an electrical machine, in the laboratory of Galvani, professor of anatomy at Bologna, and husband of the lady. An assistant had occasion to draw sparks from the machine; and each time that he did so, Signora Galvani observed that the limbs of the dead frogs moved as though alive. She called the professor's attention to the fact; he repeated the

experiment, and with the same result. But without intending it, he went farther than this, and found that the limbs of frogs could be excited as well by means of good conductors as by a machine. The power was present, and required only an efficient cause to develop its action. On examining further into the phenomenon, he ascertained that it could be produced at pleasure by touching the surface of a nerve and of a muscle at the same time with a metallic conductor.

A new explanation was soon to appear. Volta, professor of natural philosophy at Pavia, came to the conclusion that electricity was the cause of the phenomena witnessed by Galvani, and considered by that philosopher as due to some property inherent in the nerve or muscle. Volta had observed also that the excitement of the organism was greater when touched with two different metals than when only one was used, and from this result deduced the fact that the electricity resided in the metals, not in the nerves, and that bringing them together was the cause of the phenomenon. After continued application, Volta at length discovered the instrument now known as the voltaic pile. At first it was a circle of small cups partially filled with salt water, and containing plates of zinc and silver connected by wires. It was subsequently modified into its present form—a pile of alternate disks of zinc and copper kept separate by the interposition of disks of pasteboard moistened in an acid solution. At Napoleon's invitation, Volta visited Paris in 1801, and explained and illustrated his theory of contact of metals and electro-motive action to the members of the Academy of Sciences. The First Consul was one of the audience; and 'when the report of the committee on the subject was read, he proposed that the rules of the Academy, which produced some delay in conferring its honours, should be suspended, and the gold medal immediately awarded to Volta, as a testimony of the gratitude of the philosophers of France for his discovery. This proposition being carried by acclamation, the hero of a hundred fields, who never did things by halves, and who was filled with a prophetic enthusiasm as to the

powers of the pile, ordered two thousand crowns to be sent to Volta the same day from the public treasury, to defray the expenses of his journey.'

The old electricity and the new galvanism differ in many ways. Galvanism or voltaic electricity must have a continuous conductor; whereas frictional electricity will leap over short distances from one to another. The one is steady, the other uncertain. Iron can be magnetised by galvanism, not by electricity.

Oersted made a grand discovery in 1807, which he diligently pursued and reconsidered, until he arrived at his celebrated conclusion in 1819. It consists in the striking fact that the needle of a compass, when placed above or below a voltaic wire stretched from north to south, and forming a complete circuit, deviates from its normal position, and shews a tendency to place itself at right angles with the current. There is, besides, the remarkable phenomenon, that when the needle is *below* the wire, its south pole diverges to the west, if the current is passing from south to north, and to the east when flowing in the reverse direction: with the needle *above* the wire, directly opposite effects are produced. This discovery excited an admiration and activity among the learned not inferior to that which had greeted Volta. Among the foremost to elucidate the subject and extend the inquiry, Ampère stands prominent. He demonstrated the dynamical laws of the science from experiment and mathematical calculation. He considered that the battery calls into play two currents in the wire, moving in opposite directions, and thereby producing magnetic action; and shewed that similar currents circulate about the poles of a magnet. Next, Arago found that on plunging the wires of a battery into steel filings, the latter attached themselves to the wires, and remained adherent as long as the circuit was complete, but fell off on the instant of breaking contact. Here was another important step in advance: a wire could be magnetised at pleasure. It led to the invention by Mr Sturgeon, a few years later, of magnets of almost inconceivable power, by

placing a bar of soft iron within a helix of copper wire, connected with a battery. As in the case of the steel filings, it became a magnet, or ceased to be such, every time that contact was made or broken. The straight bar was afterwards bent in the form of a horse-shoe, and its attractive power so much increased in consequence, that in some instances from two to three thousand pounds have been sustained.

To enumerate the names only of those who have advanced the science of electro-magnetism, apart from any mention of their labours, would fill a long list. At the period more immediately under notice, Schweigger, De la Rive, Moll, Cumming, Barlow, Faraday, Daniell, Ohm, and Christie were multiplying facts, or deducing laws from those already known; and the labourers have since become still more numerous.

§ IV. STEPS IN THE PROGRESS OF THE SYSTEM.

THE electric, electro-magnetic, or magneto-electric telegraph was now possible; and the possibility was not allowed to remain barren of results.

How are we to understand the strange account, noticed by Addison in the *Spectator*, of Strada's mysterious apparatus? Strada, in one of his works published in 1617, said that the original idea could be traced back to Cardinal Bembo, at least as early as 1547: 'If you wish your distant friend, to whom no letter can come, to know anything, take a disk (or dial), then write round the edge of it the letters of the alphabet, in the order in which children learn them, and in the centre place horizontally a rod which has touched a magnet, movable, so that it can touch whatever letter you wish.' A similar instrument is to be made, which 'disk let the friend about to depart take with him, and agree beforehand at what time and on what days he will examine whether the rod trembles, and what letter

it points to with its index. These matters being thus arranged, if you desire privately to speak to the friend whom some shore of the earth holds far from you, lay your hand on the globe, turn the movable iron—there you see disposed along the margin all the letters which are required for words; hither turn the indicator, and the letters, now this one, now that one, touch with the style; and while you are turning the iron through them again and again, you separately compose all the ideas in your mind. Wonderful to relate, the far-distant friend sees the voluble iron tremble without the touch of any person, and run now hither, now thither; conscious he bends over it, and marks the teaching of the rod, and follows, reading here and there the letters which are put together into words; he perceives what is needed, and learns it by the teaching of the iron. And moreover, when he sees the rod stand still, he, in his turn, if he thinks there is anything to be answered, in like manner, by touching the various letters, writes it back to his friend.' Here Strada becomes impressed with the importance of his subject, for he breaks out: 'Oh may this mode of writing prove useful! Safer and quicker thus would a letter speed, nor have to encounter the snares of robbers or impediments of retarding rivers. A prince might do the whole business (correspondence) for himself with his own hands. We children of scribes, emerging from the inky flood, would then hang up our pens in votive offering on the shores of the magnet.'

Without stopping to inquire whether in this Strada wished to perpetuate the history of a lost art, or was merely giving play to his imagination, we proceed to the results of indubitable modern researches. In 1811, Soemmering proposed a scheme for a voltaic telegraph to the Academy of Sciences at Munich. It comprehended as many wires as there are letters in the German alphabet, and the numerals 0 to 9, which terminated in thirty-five gold points in a vessel of water. When the current passed from the pile, decomposition of the fluid took place, and a bubble of oxygen or hydrogen appeared at the point or letter to which attention was desired. Soemmering appears to have

been aware that the motion of electricity was swifter than that of light; and in his memoir he sets forth the advantages to be derived from such a form of telegraph—its availability by night or by day, in fog or in cloud, and its invisibility while *en route.* The contrivance, although ingenious, failed.

Schweigger soon afterwards entered the lists. He shewed that two wires would be more effectual than the greater number, and that it would not be impossible to print the communications from one end of the wire to the other—thus anticipating two of the most remarkable peculiarities belonging to the present form of electric telegraph. Schweigger next strengthened manifold the force of magnetic action by a *multiplier*, based on the fact that a current returning upon itself acts in all its parts, and causes a powerful deviation in a magnetic needle placed within it. As described by Moigno: 'A conducting wire twisted upon itself, and forming a hundred turns, will, when traversed by the same current, produce an effect a hundred times greater than a wire with a single turn; provided always that the electric fluid pass through the circumvolutions of the wire without passing laterally from one contour to another. This is a condition easy to fulfil. To make a multiplier, you take a silver or copper wire of any length or size, closely enveloped in silk thread, and wind it round a small frame, within which the needle is suspended on a pivot, and leaving a few inches free at each extremity. These are called the two wires of the multiplier, and when in work, the current enters by one end and passes off at the other.' The discovery of thermo-electricity by Seebeck is so far related to our subject, that he found that by applying heat to one extremity, or to any part of pieces of metal, they could be made to give out electric currents. One end of a short bar being raised in temperature, a circulation of a current is produced through the whole mass.

The new science was gradually assuming a definite combination. Two French *savans,* in the course of their investigations, found that a long extent of the iron of a railway could be used to complete a circuit, and bring back the reverse

current. The voltaic pile was soon replaced by batteries of various form, among which the constant battery constructed by Professor Daniell supplied the long-sought desideratum of stronger power. The zinc was plunged into a solution of chloride of sodium, and the copper into a solution of sulphate of copper. The products of decomposition were disposed of by an ingenious contrivance, and loss of power provided against, so that the action maintained its full force for a considerable period. Batteries still more powerful have since been invented: the liquids employed have been varied, and charcoal and platinum substituted for copper. One by Wheatstone required but a single liquid, sulphate of copper, in which was plunged a porous vase filled with a pasty amalgam of zinc, producing a constant action.

Thus by degrees the elements of telegraphing were prepared: there needed but the mind to combine them.

This distinction is claimed by Professor Morse, an American, having, as he says, invented the first electro-magnetic telegraph while on his passage from Havre to New York in 1832. His contrivance included a marker at one end of a wire, which, as contact was made or broken, produced an arbitrary alphabet of dots and strokes, which might represent definite characters. An experiment with a circuit of ten miles was tried before several scientific men and members of Congress; and the result being favourable, a sum of money was voted by the government for a trial on a larger scale. The account of these proceedings appears not to have been published earlier than 1837; meantime Baron Schilling of St Petersburg had constructed an electric telegraph, but died before its complete development. By his method, movements were imparted to five needles, out of which a code of signals was formed. Gauss and Weber's experiments and deductions, published in 1834, brought the possibility of electro-telegraphy still more within reach. In 1837, Steinheil of Munich succeeded in sending a current from one end to the other of a wire 36,000 feet in length, the action of which caused two needles to vibrate from side to side, and strike a bell at each movement. The bells were made to differ in tone, so as to

indicate distinctly right and left signals; at the same time, to combine a phonic and a written alphabet, certain points tipped with ink impressed dots upon a band of paper, and recorded the desired message. In the course of his researches Steinheil proved a fact of great importance—that instead of using two wires, the earth would serve to complete the circuit. It was in 1837, also, that Wheatstone, whose name is so intimately associated with telegraphic progress in England, took out his first patent for an electric telegraph. He had been led to the invention by his experiments to determine the velocity of electricity in 1834, and proposed a system of five conducting wires in connection with as many needles, which indicated the letters of the alphabet at the rate of twenty a minute. Attention was to be drawn to the signals by the stroke of a bell forming part of the apparatus. M. Vorsselman de Heer of Deventer invented an apparatus which imparted its signals through the sense of touch, and was based on the principle, that to produce an effect by this medium demands a much smaller power of electricity than to deflect a needle. He employed ten wires, and obtained forty-five different combinations, which were produced by placing the finger-tips on the keys of the instrument, and attracted the notice of the attendant by a wire attached to his person night and day: even if in bed he was to be aroused by the shock.

In 1840, Wheatstone had made improvements which greatly simplified his first methods; the number of wires was reduced to two, while the power of the instrument was increased, for thirty letters could be indicated in a minute. Besides this, the same inventor shewed that the passage of a current afforded means for other spheres of observation. Travelling at a speed that would circumvolate the globe seven or eight times in a second, it might measure the rate of motion of projectiles, or regulate the movement of all the clocks in a country; and by an additional contrivance the place of fracture in a wire could be ascertained without the necessity of examining its whole length. A telegraphic wire was to bring down from a balloon, stationary at a considerable height, the readings of a set of philosophical

instruments; to record the state of fluctuations of a barometer, thermometer, hygrometer, and magnetometer. Mr Smee combined a simple apparatus, whereby his hot-house *sent him news of its own temperature* to a distant room! With a proper combination of machinery, a lady, seated in her drawing-room in London, might play Beethoven's sonatas on the piano of her friend at Edinburgh; or a ringer in St Paul's belfry might entertain the frequenters of the Parliament Square with a lively carillon from the tower of old St Giles's. Almost equally remarkable is the application of electro-magnetism as a motive agent—with which, however, we have no concern here.

The employment of the printing apparatus in 1843 gave to the electric telegraph a wider and completer efficiency. This contrivance, when attached to the telegraph machinery, and set in motion by wheelwork, caused a ribbon of chemically-prepared paper to pass under a fine steel point, which imprinted a series of arbitrary characters—dots and strokes—simultaneously with their transmission from the other end of the telegraph, however distant. Although seventy or eighty characters could be produced in a minute, the whole process was tedious, as the message had first to be punched in a strip of paper, and then written off after its delivery. In America the preliminary punching was avoided by making the operator open or close the galvanic circuit for longer or shorter intervals, by pressing on the spring-key of the telegraph: according to the duration, strokes or dots were produced. Since that time improvements have been made which print the message in the Roman character, and accelerate the rate of transmission. Bakewell's copying telegraph is one among many departures from the system of arbitrary signs. When this means of correspondence is in operation, instead of dropping a letter in the post-office box, and waiting days for an answer, we may apply directly to the copying telegraph, have it copied at the distant town in a minute or less, and receive a reply in our correspondent's handwriting almost as soon as the ink is dry with which it was penned. There are various means, too, for preserving the secrecy of correspondence; the most curious of

which is, that the writing may be rendered nearly invisible in all parts but the direction, until its delivery to the person for whom it was designed.

The success that has attended the progress of electro-telegraphy has, as is usual in such cases, called up a host of claimants to the various inventions or discoveries. We are, however, too apt to overlook the fact, that discovery is rather the consequence of tendencies of thought and progress on the part of numbers, than of sudden individual conception. The elaboration of a great moral or scientific truth, and its application to the well-being and advancement of society, are results not less honourable to those who have assisted in producing them than to the prime originator—if such there be: remembering always, that but for the thought and travail of previous generations, our own achievements would be slender indeed. There have been frequent renewals of controversy, whether this or that person is the inventor of the electric telegraph. The claims of Mr Ronalds, for instance, have lately been brought forward, on the ground that he sent signals, by frictional electricity, through eight miles of wire at Hammersmith in 1816; that he proposed, about that time, the adoption of an electric telegraph by the Admiralty; and that, in a volume published on the subject in 1823, he said: 'If he [the author] should be proved competent, why should not our kings hold councils at Brighton with their ministers in London? Why should not our government govern at Portsmouth almost as promptly as at Downing Street? Why should our defaulters escape by default of our foggy climate? And since our piteous *innamorati* are not all Alphei, why should they add to the torments of absence those dilatory tormentors, pen, ink, paper, and post? Let there be electric-conversation offices, communicating with each other all over the kingdom.' These were remarkable words, certainly, to be uttered so far back as 1823. No *one* person, however, let it be now distinctly admitted, invented the electric telegraph.

§ V. CHIEF CHARACTERISTICS OF TELEGRAPHING.

At length we come to the actual use of electric telegraphs for commercial purposes, as parts of a regular system.

The first, or nearly the first, example was afforded by the Blackwall Railway, opened in 1840. In the four miles from the Minories to Blackwall, there were intermediate stations at Shadwell, Stepney, Limehouse, West India Docks, and Poplar. The trains were drawn, not by locomotives, but by rope-traction, with the aid of fixed steam-engines. The trains started every quarter of an hour in each direction. The announcements of departures, of stoppages, of the number of carriages attached to the wire-rope, of accidents or causes of delay, were regularly transmitted by electro-telegraphic apparatus placed at all the stations, and the business was thereby maintained in full vigour and discipline.

Circumstances led the Blackwall Company to substitute locomotive for fixed power; but the value of the electric telegraph had been rendered too manifest to permit of its abandonment. Many of the railway companies deemed themselves justified in laying down a single instead of a double line of rails, owing to the safeguards which the telegraph afforded. By the year 1842, the system had been adopted on the London and North-Western, South-Western, South-Eastern, and Eastern Counties lines. On the Great Western the wires at first were placed inside a continuous tube, fixed a few inches above the ground at one side of the line, but were afterwards strained on posts as on other railways. This wire had not long been complete when a striking instance occurred of the service which the telegraph might render to society. A man of respectable exterior took his seat in a first-class carriage at the Slough station, eighteen miles from

London: he was a murderer hurrying away from the yet warm body of his victim. The panting engine neared its destination; the eager criminal believed his escape certain; but the alarm had been given at the fatal spot, and quick as lightning the telegraph transmitted it to Paddington, with a description of the suspected individual. In three minutes an answer announced the arrival of the train, the identification of the fugitive, and the certainty of his capture. A deep impression was made on the public mind by this victory of science and justice over crime. Again, a communication transmitted from Paddington immediately that the year 1845 commenced, was received at Slough in 1844, the clock at that place not having struck midnight. Though so short a distance, the difference of longitude was sufficient to mark the inconceivable velocity of the electro-magnetic current. Swift-footed Time was henceforward to be beaten in the race. A still more remarkable instance of the same nature occurred in America: a message flashed from Washington when the new-year was a quarter-hour old, was read off at New Orleans with half an hour of the old year yet to run.

The first newspaper enterprise in electro-telegraphy seems to have been the report of a public meeting in 1845. Portsmouth was wild with excitement about two railway schemes in parliament; a meeting was held, and the result was anxiously awaited in London, where one of the newspapers printed it very soon after the meeting broke up. This success incited Southampton, where the proprietors of one of the newspapers resolved to print the Queen's speech without waiting for the railway. The speech was telegraphed letter by letter; and the 3600 letters were set up in type at Southampton two hours after the delivery of the speech. After this, the only limit was the expense; any newspaper proprietors who were willing to bear the cost could receive telegrams* to fill their columns to any extent they

* When the name *telegram* was introduced, Greek scholars disputed about its correctness; but the public found it so useful as to dispense with etymology altogether; and it is now incorporated indelibly in the English language.

pleased. The Admiralty, convinced of the advantages of the system, adopted it in 1848 as a substitute for the old semaphore.

The wire commonly used for those early telegraphs, and the general organisation, were not exactly such as are now adopted; we may describe the present arrangements in the following brief outline. The wire is usually about one-sixth of an inch diameter, covered with a thin coating of zinc, or, as it is called, 'galvanised,' to prevent oxidation. Besides this, it is found that the deposit from damp and dust and other causes affords a very efficient protection. Four miles of such wire weigh a ton. The posts to which it is attached are fixed at from fifty to sixty yards apart—thirty or thirty-two to the mile. To insure perfect insulation, the wires are not permitted to touch the posts, otherwise the current would be diverted downwards through the wood, particularly in wet weather. Insulators of various forms, rings, collars, and double cones, are made of ebonite, porcelain, glass, white earthenware, or brown stoneware. Besides the supporting-posts, there are others called 'winding-posts,' four to the mile, to which the wires are connected in alternate half-mile lengths, and stretched by means of a screwing apparatus. It is on these posts that the insulators are placed; a sufficient number being attached to each side, the wire is passed through the eye and drawn tight; while, to maintain the communication uninterrupted, a loop of wire is affixed to the main lengths at a short distance on either side of the post, round the front of which it passes in a slight curve. To protect the insulators as much as possible from wet, they are sheltered by a sloping wooden roof. The pointed wire seen rising a few inches above the tops of the posts on some lines is a lightning-conductor with its lower extremity buried in the earth: a precaution not unnecessary, as thunder-storms produce singular effects on the lines of telegraph.

One wire will suffice for the transmission of correspondence between any two places; the making use of a greater number—six, eight, or ten, as may be seen on some railways—is merely for the sake of economy or convenience. It is found better in

practice to keep one or two wires distinct for the main termini or points of correspondence—say from London to Liverpool—than to make them serve at the same time all the intermediate stations. It is an arrangement which helps to simplify the working duties of the office, and to facilitate them also; for with but one or two wires there would be constantly-recurring delays and confusion, since while any two places were intercommunicating, all the others would have to wait. One of the wires is sometimes employed exclusively for the alarums—that is, to ring the bell at any station with which it may be desired to 'speak.' Wherever connection is made with an intermediate office, the main wire is temporarily cut off or shut out from this distant terminus.

The wires, when in their place, are connected with galvanic batteries and telegraphic instruments at the respective stations. Here it becomes necessary to consider the construction and action of a battery. The latter may be familiarly described as a wooden trough, from 2 to 3 feet long, and about 6 inches wide, divided crosswise into twenty-four compartments or cells—more or fewer according to circumstances—by partitions of slate. Two plates of metal, copper and zinc alternately, are placed in each cell, in such an order that all the plates of one kind face towards one end of the trough, and all of the other kind to the other end. A small strip or ribbon of copper unites each pair at the centre of their upper edges, forming, as it were, so many curved handles, by which they can be lifted in and out. As soon, then, as the remaining vacant space in each cell is filled with an acidulated fluid, the action commences; the acid begins to act on the zinc by dissolving it, the water contained in the solution is decomposed, and hydrogen thrown off from the surface of the copper plates; while by a combination of oxygen, oxide of zinc is formed, and this dissolving in the acid—which is commonly sulphuric—sulphate of zinc is produced. A positive current is generated at the zinc, and passes to the copper through the intervening fluid in all the series of cells, and continues to flow as long as contact is maintained between

the wires which depart from either end, whatever be their length.

The cells of telegraph batteries, instead of a fluid, are filled with pure sand, a material chemically inert, moistened by pouring in the dilute sulphuric acid—an arrangement which admits of the apparatus being removed from place to place without risk of spilling the contents, while it diminishes waste of the plates without diminishing their power. The zinc is most liable to dissolution, and would be rapidly exhausted were it not for the protective influence of an amalgamating process, now frequently adopted. A well-prepared battery, with occasional renewals of the acid, will maintain an effective working condition during twelve or fifteen months.

The wires of the battery meet those of the telegraph in what is called the electro-magnetic machine, which externally resembles a cabinet clock, having a square dial-plate inscribed with the letters of the alphabet and certain arbitrary characters, and two hands placed side by side near its centre. These hands are the needles which are the tongues of the apparatus; in their vibrations to the right and left, their starts and pauses, the whole correspondence is conveyed. For each needle visible on the face of the instrument there is a corresponding one inside, the two being so placed that the north pole of the one and the south pole of the other are in the same position, so as to neutralise their magnetism, or rather the action of magnetism upon them. They are thus kept in a perpendicular position, and obedient to the slightest impulse from the battery. The inner needle is suspended within a coil or multiplier, which intensifies the power of the current at this particular spot, and is deflected to either side at pleasure by movement of the levers or handles which close or open the electro-magnetic circuit. The wires finish in two terminals, which form part of the mechanism, and are in connection with the magnet and the multiplier. The battery-wires are brought to two other terminals, connected also with the same apparatus; so that in order to reach the telegraph-wires, the current must first excite

the magnet and the needles. This action takes place only when work is to be done; at other times the circuit is left open. Instantaneously, however, on making contact, the signals exhibited at one end of the line are reproduced at the other; such is the astonishing power of the magnet when rendered active. Messages of business or friendship, congratulation or anxiety, may be sent from one end of the kingdom to the other with the velocity of lightning. With all this speed, however, there is no actual motion, no absolute passage of a fluid. It is only that, by a law of polarity, one molecule affects the other next to it; and so on *ad infinitum*, and with almost inappreciable celerity, as long as the exciting cause remains.

When a message is to be sent, the clerk whose duty it is to work the instrument places the written document before him; and after striking the 'ringing key,' to call the attention of his correspondent, takes one of the levers which project from the base of the machine in each hand, and moving them from side to side produces corresponding and simultaneous movements of the needles on his own and the distant dial-plate; the words are thus spelt off with great facility. Such is the quickness of apprehension acquired by practice, that the clerks can write the message as fast as the needles deliver it; and it is said that some of the more expert would be able to read it without error from a blank dial. To expedite transmission, the communications are made as brief as possible by the elision of letters and syllables, and sometimes of half a word; besides which, many conventional signs are made use of for full stops, paragraphs, italics, &c.; and there is even a signal among the clerks for laughing, and one for the *whistle* of astonishment. Where secrecy is desired, any two parties have only to agree to employ numerals as letters, or to reverse or transpose the alphabet at pleasure, in order to form a code of signals which none but themselves shall be able to interpret. The messages transmitted on the Admiralty service are based on a private system, of which the chiefs alone understand the purport.

With respect to the telegraph system as it was in 1850, let us

see what Mr C. V. Walker said of it. 'The rate at which newspaper dispatches are transmitted from Dover to London is a good illustration of the perfect state to which the needle-telegraph has attained, and of the apt manipulation of the officers in charge. The mail, which leaves Paris about mid-day, conveys to England dispatches containing the latest news, which are intended to appear in the whole impression of the morning paper. To this end it is necessary that a copy be delivered to the editor in London about three o'clock in the morning. The dispatches are given in charge to us at Dover soon after the arrival of the boat, which of course depends on the wind and the weather. The officer on duty at Dover, having first hastily glanced through the manuscript, to see that all is clear and legible to him, calls 'London,' and commences the transmission. The nature of these dispatches may be daily seen by reference to the *Times*. The miscellaneous character of the intelligence therein contained, and the continual fresh names of persons and places, make them a fair sample for illustrating the capabilities of the electric telegraph as it now is. The clerk, who is all alone, placing the paper before him in a good light, and seated at the instrument, delivers the dispatch, letter by letter, and word by word, to his correspondent in London; and although the eye is transferred rapidly from the manuscript copy to the telegraph instrument, and both hands are occupied at the latter, he very rarely has cause to pause in his progress, and as rarely also does he commit an error. And on account of the extremely limited time in which the whole operation must be compressed, he is not able, like the printer, to correct his copy. At London there are two clerks on duty—one to read the signals as they come, and the other to write. They have previously arranged their books and papers; and as soon as the signal for preparation is given, the writer sits before his manifold book, and the reader gives him distinctly word for word as it arrives; meanwhile a messenger has been despatched for a cab, which now waits in readiness. When the dispatch is completed, the clerk who has received it reads through the

manuscript of the other, in order to see that he has not misunderstood him in any word. The hours and minutes of commencing and ending are noted; and the copy being signed, is sent under official seal to its destination, the manifold facsimile being retained as our office-copy, to authenticate verbatim what we have delivered.'

Instances are given to illustrate the singular services rendered. 'On 11th December 1849, to the great astonishment of the merchants and bankers of Paris, three gentlemen appeared on 'Change in that city, at half-past one P.M., having with them 150 copies of the *Times*, printed and published in London on the morning of the self-same day; and not only did the *Times* contain the Paris news up to noon of the previous day, but actually the closing prices of the Paris Bourse of the previous evening. The electric telegraph contributed in no small degree towards the accomplishment of this feat. At eight minutes past one A.M., the dispatch of 321 words, and the Bourse prices, equal to 55 words, were delivered into our charge at Dover, having been conveyed thither from Calais in the ordinary mail-boat. In exactly thirty-two minutes—namely, at forty minutes past one—a correct copy of both these documents was handed in by us to the *Times* Office in London. The dispatch occupied us eighteen minutes, being at the rate of $17\frac{5}{8}$ words per minute; the Bourse prices, two minutes. In respect to the latter, the rate is high, because the larger portion is anticipated, the mere fluctuations being all that is new.'

It is useful to refer to the above account, because the prodigious spread of railways and the improvement of the telegraphic system enable the world, in 1866, to far outstrip the doings of 1850. Since the last-named year, the *magneto-electric machine*, an instrument of great value and importance, has been largely used as a substitute for the galvanic battery in telegraphy.

The proprietors of telegraphs inform us that the communications intrusted to them for delivery comprise the whole catalogue of human wants and wishes, business and pleasure, joy and sorrow, friendship and law. On some occasions they have

been asked to send a sum of money or a small parcel along the wire, by individuals, too, whose surprise shewed the sincerity of their belief that the instrument could perform what was desired. Games of chess are played between parties in distant towns, the moves being flashed from place to place alternately, as fast as they are made. Then the security which the telegraph lends to railway travelling is not the least of its merits: accident and obstruction can at once be made known, and the remedy provided. On one occasion a collision had occurred to an empty train at Gravesend; and the driver having leaped from his engine, the latter started alone at full speed to London. Notice was immediately given by telegraph to London and other stations; and while the line was kept clear, an engine and other arrangements were prepared as a buttress to receive the runaway. The superintendent of the railway also started down the line on an engine; and on passing the runaway he reversed his engine, and had it transferred at the next crossing to the up-line, so as to be in the rear of the fugitive. He then started in chase, and on overtaking the other he ran into it at speed, and the driver of his engine took possession of the fugitive, and all danger was at an end. Twelve stations were passed in safety; it went by Woolwich at fifteen miles an hour, and was within a couple of miles of London before it was arrested. Had its approach been unknown, the mere money-value of the damage it would have caused might have equalled the cost of the whole line of telegraph. Instances of this kind are numerous.

The promptitude with which detection has followed fraud by the agency of the telegraph, is sometimes very striking. On one particular evening, at ten o'clock, the chief cashier of a bank received a notice from Liverpool, by electric telegraph, to stop certain notes. The next morning the descriptions were placed upon a card and given to the proper officer, to watch that no person exchanged them for gold. Within ten minutes they were presented at the counter by an apparent foreigner, who pretended not to speak a word of English. A clerk in the office who spoke German interrogated him, when he declared

that he had received them on the Exchange at Antwerp six weeks before. Upon reference to the books, however, it appeared that the notes had only been issued from the bank about fourteen days, and therefore he was at once detained on suspicion. A letter was written to Liverpool, and the real owner of the notes came up to town on the next morning. He stated that he was about to sail for America, and that whilst at a hotel he had exhibited the notes. The person in custody advised him to stow the valuables in his portmanteau, as Liverpool was a very dangerous place for a man to walk about with so much money in his pocket. The owner of the property had no sooner left the house than his adviser broke open the portmanteau, and stole the property.

§ VI. NEW COMPANIES AND NEW CONTRIVANCES.

THE many wonderful improvements in the details of electro-telegraphy have been intimately associated with the formation of joint-stock companies for developing the system.

The *Electric Telegraph Company* was incorporated in 1846, with a central establishment in Lothbury. The building was amply furnished with all the requisites for telegraph service; and by means of wires laid in tubes under the surface of the streets, was connected with all the metropolitan railway stations, the post-office, the head police station in Scotland Yard, the Admiralty, the new Houses of Parliament, Buckingham Palace, and many other public buildings. Besides these, communications were complete with different places in the provinces, including the chief towns and outports. Electric telegraphs, according to the parliamentary enactment, 'shall be open for the sending and receiving of messages by all persons alike, without favour or preference, subject to a prior right of use thereof

for the service of Her Majesty, and for the purposes of the company.' A proviso is also made in favour of the Secretary of State, who may, on extraordinary occasions, take possession of all the telegraph stations, and hold them for a week, with power to continue the occupation should the commonweal require it. There were established in Edinburgh, Manchester, Liverpool, Glasgow, Hull, Newcastle, and other towns, subscription news-rooms, for the accommodation of the mercantile and professional interests, to which was transmitted by electric telegraph the latest intelligence, including domestic and foreign news; shipping news; the stock, share, corn, and other markets; parliamentary intelligence; London Gazette; state of the wind and weather from numerous places in England; and the earliest possible notices of all important occurrences.

In 1850, a second association was incorporated, known as the *British Electric Telegraph Company*, for the purpose of telegraphic communication upon a more economical scale throughout the country, and for the purchase and use of patents. The company's central office is in Threadneedle Street.

To notice all the wrangles between those two companies, and others of later introduction, is beside our purpose. Suffice it to say, that the companies have settled down into the *Electric and International*, the *British Electric*, the *British and Irish Magnetic*, the *London District*, and the *United Kingdom*, besides one or two small affairs. Some of them have underground wires, contained in tubes; but by far the larger number have wires on poles along the railways. Some use the needle-telegraph, some the dial instrument. Very little has yet been done in England, although much has been talked and written, to bring *printing* or *recording* telegraphs into use for commercial purposes; the public are still mainly dependent on written transcripts of the messages. Since the *United Kingdom Company* established shilling telegrams without reference to distance, in 1861, a hope has been entertained that this low charge will be remunerative; but hitherto it has been barely successful. What kind of tariff will eventually be found best, there is insufficient evidence yet to shew. The

high charge for the continental telegrams enables some of the other companies better to stand their ground.

The *Overhouse Telegraph*, belonging to the London District Company, is a curious one. Messrs Waterlow, a commercial firm in London, were among the first to introduce the system, by stretching an overhouse wire between two of their establishments. By permission of the inhabitants, they erected posts on some of the intervening house-roofs, and stretched the wire from post to post. The same plan has been adopted in Paris, Brussels, New York, and other cities, for local purposes. A company, to carry out the scheme on a large scale in the metropolis, was formed in 1858. They took a circle of eight miles diameter, with Charing Cross in the centre, and divided this into eleven districts, each containing eight to a dozen stations. There was one chief station to every district, and subordinate to these were local stations. All the district stations were connected by the nearest practicable routes, and all local stations were placed in direct communication with the chief station of each particular district. Permission was to be obtained (sometimes by purchase) to erect telegraphic poles on the roofs of houses and public buildings; with facility of access for repair, renewal, &c. The original plan, with a few modifications, has been gradually put in force. In the summer of 1866, there were about 150 of these stations in the metropolis, some of them beyond the four-mile radius. A message is sent from any station to any part of the metropolis at a charge of fourpence to sixpence, including delivery by a messenger from the second or receiving station. Government messages, civil or military; summoning witnesses and lawyers to the law-courts; announcements of births, marriages, and deaths; sending for medical aid in urgent cases; giving notice to fire-brigades when and where their services are needed; 'sending for the police,' in cases of tumult or the like; announcing to friends an arrival or departure at a railway station; inquiring whether a friend is 'at home' before you go to visit him; giving and accepting invitations; making or postponing appointments; corresponding between the

business house and the suburban residence of a City man; aiding the larger telegraph companies in collecting and distributing their messages; attaching local wires for the accommodation of particular persons or firms at particular spots—all these duties come within the scope of the Overhouse Telegraph Company.

The great destruction of overhouse wires, during a fierce wind-storm early in 1866, led to a suggestion for stretching the wires on lofty posts fixed in the curb-stones of the streets, thereby avoiding both overhouse and underground arrangements. Many things would have to be taken into consideration, before such a plan could be adopted.

Although, as was stated in a former paragraph, printing or recording telegraphs are not in very general use in England, it is necessary briefly to notice their chief characteristics. *Morse's* telegraph marks a series of dashes and dots, the lengths, positions, and distances of which are made to denote different letters and symbols; the transmitting instrument marks the dashes and dots on one slip of paper, the receiving instrument on another, and a code-book translates these symbols into English. This system, but with ink marks instead of embossed dashes and dots, is more adopted on the continent than any other. *Steinheil's* system makes the symbols by variously-distributed dots, without dashes, on chemically prepared bands of paper. *Whitehouse's*, *Allan's*, *Thomson's*, and some other systems, are diverse modes of employing the dot system. Sometimes the mechanical apparatus for making the dashes and dots is worked by a hand-lever; sometimes by pressing down keys instead of moving levers. *Digney's* system marks the dots with ink, supplied in a peculiar way from a felt roller. *Wheatstone's Universal* system punches holes clean through a strip of paper, the arrangement of the holes denoting the kind of word or code-signal intended to be conveyed; it can send 160 letters per minute. *Siemens and Halske's* system produces indentations (without ink) by means of peculiarly shaped metal types. *Bonelli's* system *prints the message in Roman type*, or something between Roman and Egyptian—all capitals, about an eighth of

an inch high. This is perhaps the most wonderful and beautiful of all the systems. A message, say from London to Edinburgh, is transmitted through a wire or wires, and then prints itself in legible characters in the Edinburgh office on a slip of paper, which may be kept as a record of the transaction. Commercial rather than mechanical difficulties have, we believe, retarded the spread of this method. *Rogers's* system makes ink marks on a brass disc, easily rubbed off when the telegram has been recorded. *House's* system is one of those which print the message in ink with Roman type; and *Hughes's* (now coming much into use in France) is another. *Bain's* system—or rather one of several by the same inventor—makes rows of stain spots on strips of paper. *Brett's* system acts by studs pressing on a circle of printing types charged with ink. *Bakewell's* system gives an exact copy of the handwriting transmitted—even a portrait or profile. *Caselli's pantelegraph*, an improvement on Bakewell's, has the writing put with ordinary ink on silver paper, and the copy received in blue on a white ground. There are others besides these, of great scientific beauty. The needle-telegraph is, however, still the one most used for railway-station work, because the apparatus is simple, easy to learn and to work, and easy to repair. A story, illustrative of this facility of treatment, is told of a station telegraphic clerk, who, when drowsy, ordered his dog to watch the instrument. When this supernumerary but faithful assistant heard the click, and saw the two index-pointers move, his bark roused his master to attend to the receipt of some message from a distant station.

Perhaps the Metropolitan Railway illustrates the value of the electric telegraph more strikingly than any other yet constructed. On a line five miles long, mostly underground, from Paddington to Finsbury, there are nine stations, through which nearly two hundred trains a day pass in each direction. In the darkness of the tunnelled route one train would almost certainly run into another occasionally, were there not special precautions taken. The plan adopted is, to forbid a train to quit one station until the next station in advance is clear, on the same line of rails,

and the distance also clear between the one station and the other. This is effected by electric signals at every station, when a train is coming or going, sending the proper message to the two adjacent stations. Mr Spagnoletti's apparatus for this purpose is very beautiful.

Gradually, like most good and useful things, the telegraphic system has grown among us to a position of great magnitude. In 1850, there were three thousand miles of magic wire talking in the United Kingdom. In 1852, the length of line (averaging four or five wires each) was 4000 miles, supported by 80,000 poles, and worked at 300 railway stations. By the year 1861, the United Kingdom was credited with 11,000 miles, comprising 50,000 miles of wire. Coming down to 1865, we find an estimate to the effect that there were 15,000 miles of line; that these were made of 62,000 miles of wire; that there were 900 telegraph stations; that the companies had spent £2,500,000, of which £400,000 was for the purchase of patented inventions; that they transmitted 2,500,000 telegrams in the previous year; that these telegrams brought in £500,000; and that the working expenses were 65 per cent.

If this were a fitting place to notice the opening of new industrial employments for women and girls, we might dwell at some length on what is now doing at the telegraph-offices in England; but a few words must suffice. At the central office of the Electric and International Telegraph Company, in Telegraph Street, Moorgate Street, about two hundred young women, under the careful supervision of a matron, are employed all day long in transmitting and receiving telegraphic messages. The branch-offices in London receive messages which are to be sent into the country; these messages are, chiefly by an ingenious system of underground pneumatic tubes, quickly forwarded to Moorgate Street; whence they are sent off as telegrams by the feminine workers at the instruments. It is a condition of employment that the young women, who range from eighteen up to twenty-five years of age, should be unmarried; as it is considered that maternal and domestic duties would interfere

with the strict system necessarily observed. Some have been governesses, some orphans of professional men, some the daughters of tradesmen who cannot afford to keep them at home unemployed. There are comfortable rooms in which they take dinner or tea, under very economical but satisfactory arrangements. Telegraphing by night as well as by day being carried on in this central office, clerks are necessarily employed at all hours; but this is men's duty, the young women never being engaged at night-work. The rate of earning varies from ten to as much as thirty shillings per week, according to the degree of skill attained. As situations in such an office are eagerly sought for, the company exercise a careful system of selection; and there are always many more candidates than there are vacancies for them. Various degrees of intelligence are soon made manifest in this kind of employment; either by errors of signalling or of transcribing, very absurd telegrams are received sometimes. The newspapers speak of one in which '*Johnson's Poem on Plato*' was transformed into '*John Pomers on Plate Money!*'

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§ VII. LAND TELEGRAPHS IN FOREIGN COUNTRIES.

We must next glance rapidly at the achievements of other nations in spreading the electric wires over the face of the earth —leaving for separate notice what *all* have been doing, at home and abroad, in carrying the wonderful messenger through seas and oceans.

France.—The spread of electric telegraphs in France was for a long time extremely slow. The government refused to abandon their well-developed system of semaphore telegraphs; and when with much reluctance they were induced to avail themselves of the infinitely superior agency of electro-magnetism,

they stipulated that the signals should still be produced by small instruments, counterparts on a diminutive scale of the apparatus contrived by Chappe. There were, however, too many practical difficulties in the way; and ultimately the absurd condition was withdrawn in favour of machinery similar to that used in this country, the government reserving to itself the exclusive use and control of the lines. In 1845 and two following years, the telegraphs extending from Paris to Orleans, to Rouen, to Lille and Calais, to the Belgian frontier, and to Versailles, were commenced and brought into operation. The results were such, that in 1850 a commission was appointed to inquire further into the subject.

The commissioners drew up a favourable report, recommending the formation of additional lines, and the plan of stretching the wires on posts in preference to placing them in tubes underground; and that the telegraphs should be open to the use of the public. Among other economical advantages to result from the further extension, was the saving of locomotive power on railways; for, in accordance with the practice on the French lines, whenever a train was twenty minutes late an assistant-engine was despatched to its relief from one station after another all along the route—an arrangement which not only involved considerable expense, but liability to accident also. The construction of seven telegraphic lines was recommended; soon afterwards, five of the number were officially authorised—from Paris to Tonnerre, Rouen to Havre, Paris to Angers, Orleans to Châteauroux, and from the same city to Nevers; and by a vote of the Assembly, 717,095 francs were set apart to defray the expenses of the necessary works. To afford the fullest facilities to the government, wires were led from the respective stations in Paris to the office of the Minister of the Interior. The charge was so high, that, to send a message of 300 words from Paris to Calais (185 miles) would cost more than 35 shillings. From 75 to 80 letters were transmitted per minute. The telegraphs complete and in progress in France in 1850 were 1500 miles in length.

By degrees, new inventions and improvements have been introduced, including Hughes's apparatus, and a form of Morse's which marks with ink instead of embossing. The iron wires are about the same thickness as those used in England, $\frac{1}{6}$ inch. In the one country as in the other, the wires now connect almost every important town with the general net-work. No less than 400 tons of telegraphic wire were ordered by the French government in one year.

Belgium.—In Belgium, a commission was appointed at the close of 1849 to consider the subject of telegraphs: the individuals named—one being M. Quetelet—were eminently qualified for their duties. After a careful examination of the systems of electro-telegraphic communication employed in other countries—the burying of the wires underground, as in Prussia, and the stretching of them on posts, as in England and the United States—the liability to accident from premeditated mischief, atmospheric or other causes—they decided in favour of wires above rather than below the surface. They shewed that the disturbances to which the apparatus is liable from electricity of the air is nowhere so effectually guarded against as in England, where conductors are attached to the posts and to the machinery in the offices; and they recommended the adoption of similar means of protection on the Belgian lines. The first lines recommended and made were from Brussels to Quiévrain—and to the Prussian frontier; from Malines to Ostend by way of Ghent—and to Antwerp—the several distances amounting to about 300 miles. The central situation of Belgium with regard to other countries rendered the formation of these lines of essential importance in continental communications; and now Belgium fully rivals England in the closeness of the net-work formed by the various lines which have been constructed.

Europe generally.—Every country in Europe, even the most thinly populated, is gradually feeling the benefit of this wonderful medium of communication. A writer, so far back as 1850, said: 'Already the ramifications of electro-telegraphs extend from one end of Europe to the other: the lines to connect

Petersburg with Moscow, and with the Russian ports on the Black Sea and the Baltic, are in progress; other wires stretch from the capital of the czar to Vienna and Berlin, taking Cracow, Warsaw, and Posen on the way. Two lines, by different routes —Olmütz and Brunn—unite Vienna with Prague, from whence an offset leads to Dresden; a third enables the Austrian government to send messages to Trieste—their outport on the Adriatic —325 miles distant; a fourth communicates with the metropolis of Bavaria; and since the 10th January (1850), the *Gazette d'Augsburg* has published the course of exchange in Munich twenty minutes after it has been declared in Vienna. Calais may send news to the city of the Magyar on the Danube; and ere long intelligence will be flashed without interruption from St Petersburg to the Pyrenees. Tuscany has 190 miles of telegraph under the direction of Signor Matteucci; and a single wire, traversing the level surface of the Netherlands, unites Rotterdam with Amsterdam. Communities are learning that the electric telegraph is an essential of good government; that police without it is inefficient; that by it the better interests of humanity are promoted. There is talk also of introducing the thought-flasher into that land of wonders—Egypt; to stretch a wire from Cairo to Suez for the service of the Overland mail. Who shall say that before the present generation passes away, Downing Street may not be placed in telegraphic *rapport* with Calcutta?' Since that year, the progress has been so rapid that it was estimated in 1861 Europe contained 100,000 miles of telegraphic wire; and in 1865, Downing Street really was 'placed in telegraphic *rapport* with Calcutta.'

A Telegraph Conference was held in 1865, at which sixteen foreign governments were represented, to agree upon a system for working all the continental telegraphs upon one harmonious plan. But some curious difficulties arose out of the unwillingness of some of the governments to admit telegrams in *cipher* or other unfamiliar language—in dread of political intrigues and plottings.

Asia.—In Asia, land-wires extend through Asia Minor to the

Euphrates; through the principal towns of Persia and Mesopotamia to the head of the Persian Gulf; through the whole of India, from north to south and east to west. And now Russia is carrying wires right across Siberia, to join a short submarine cable immersed in Behring's Strait; whereby Asia and America will be joined by telegraph. As to India, nearly all the chief cities are united by the magic wire—Kurrachee, Moultan, Lahore, Delhi, Agra, Lucknow, Allahabad, Benares, Calcutta, Madras, Bombay, &c. One commercial house alone, Messrs Crawford's, was stated, in 1865, to be paying £3000 a year for telegrams to and from India. It is now admitted, however, that some of those land-wires are very badly managed, and do not render the amount of service which might reasonably be expected from them.

Australia.—The southern hemisphere has not failed to shew itself alive to the advantages of this wonderful aid to the communication of thought. All the governments on the mainland of Australia (excepting, perhaps, the sleepy colony of Swan River or Western Australia), as well as those of Tasmania and New Zealand, now possess lines of telegraph. Melbourne, Adelaide, Sydney, Brisbane, and many towns of secondary rank, are connected by wires; and the total length in that part of the world now reaches several thousand miles.

America.—It is in the United States of America that the electric telegraph has been most extensively developed and applied. Growing coincidently with the system so successfully worked in our own country, an almost limitless breadth of territory has necessitated a proportionate extension of the wires. The lines in many instances are carried across the country, regardless of travelled thoroughfares; over tracts of sand and swamp; through the wild primeval forest, where man has not yet begun his contest with nature—where even the rudiments of civilisation are yet to be learned. Away it stretches, the metallic indicator of intellectual supremacy, traversing regions haunted by the rattlesnake and the alligator—solitudes that re-echo with nocturnal howlings of the wolf and bear. Economy and

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rapidity of construction were prime desiderata; and to insure the proper working of the telegraph in its direct course across the country, the settlers who lived near the line were at first permitted to make use of it on condition that they kept it in repair. By this means communications were maintained from north to south, east and west, through all the length and breadth of the mighty Union, and with a frequency and social purpose exceeding that of any other nation. From the frontiers of Canada at Burlington, and from Halifax in Nova Scotia, a line passes to Boston, and thence in a southerly direction till it reaches the Gulf of Mexico at New Orleans—a distance of 2600 miles. It connects all the great cities of the Atlantic coast—New York, Philadelphia, Baltimore, Washington, Richmond in Virginia, Raleigh and Columbia in South Carolina, Augusta in Georgia, and Mobile in Alabama. In one stretch Maine and Vermont, where winter with deepest snows and arctic temperature usurps six months of the year, are united with the lands of the tropics, where the magnolia blooms and palm-trees grow in perpetual summer. From New Orleans another nerve of wire threads the valleys of the Mississippi, Missouri, and Ohio; subordinate lines bring the great lakes—the inland seas—into direct communication with the ocean-ports on the eastern shore; and other wires cross the Rocky Mountains to California and Oregon. In some instances, the rivers are spanned by wires stretched on tall poles, or laid in tubes of gutta percha along the bottom of the wider channels or estuaries. Nothing stops the restless, enterprising spirit of the people; and their project for uniting the Atlantic with the Pacific, New York with San Francisco, has been fully realised.

The scale of charges in the United States is much lower than in this country: the electric telegraph is consequently more available to the greater part of the population engaged in commercial affairs. The transmitting apparatus used on the different lines is that severally invented or contrived by Morse, House, and Bain. On the meeting of the legislature at Albany in 1847, the governor's message, 25,000 letters, was flashed to

New York, 150 miles distant, and printed at the same time in two hours and a half. The president's message, on the war with Mexico, was transmitted from Washington to Baltimore, 40 miles, and permanently recorded at the rate of ninety-nine letters a minute. During the popular disturbances at Philadelphia in 1844, 'sealed dispatches were sent by express from the mayor of Philadelphia to the president of the United States. On the arrival of the express at Baltimore, the purport of the dispatches transpired; and while the express train was in preparation, the intelligence was sent on to Washington by telegraph, accompanied by an order from the president of the railroad company to prevent the burden-train from leaving until the express should arrive. The order was given and complied with. The express had a clear track, and the president and cabinet (being in council) had notice both of the fact that important dispatches were on the way to them, and of the nature of those dispatches; so that when the express arrived, the answer was in readiness for the messenger.' Again: 'When the *Hibernia* steamer arrived at Boston in January 1847, with news of the scarcity in Great Britain, Ireland, and other parts of Europe, and with heavy orders for agricultural produce, the farmers in the interior of the state of New York, informed of the facts by magnetic telegraph, were thronging the streets of Albany with innumerable team-loads of grain, almost as quickly after the arrival of the steamer at Boston as the news of that arrival could ordinarily have reached them.'

Apart from business and politics, the Americans have made the electric telegraph subservient to other uses: medical practitioners in distant towns have been consulted, and their prescriptions transmitted along the wire; and a gallant gentleman in Boston married a lady in New York by telegraph—a process which might supersede the necessity for elopement, provided the law held the ceremony valid. Music, or at least the rhythm of music, has been conveyed by the same wonderful agency. An observer of the fact in New York says: 'We were in the Hanover Street office when there was a pause in business

operations. Mr W. Porter of the office at Boston asked what tune we would have. We replied "Yankee Doodle," and to our surprise he immediately complied with our request. The instrument commenced drumming the notes of the tune as perfectly and distinctly as a skilful drummer could have made them at the head of a regiment; and many will be astonished to hear that "Yankee Doodle" can travel by lightning. We then asked for "Hail, Columbia!" when the notes of that national air were distinctly beat off. We then asked for "Auld lang-syne," which was given, and "Old Dan Tucker," when Mr Porter also sent that tune, and, if possible, in a more perfect manner than the others. So perfectly and distinctly were the sounds of the tunes transmitted, that good instrumental performers could have had no difficulty in keeping time with the instruments at this end of the wires.'

The telegraph is used in America by all classes, except the very poorest—the same as the mail. A man leaves his family for a week or a month; he telegraphs them of his health and whereabouts from time to time. If returning home, on reaching Albany or Philadelphia, he sends word the hour that he will arrive. In the towns about New York the most ordinary messages are sent in this way: a joke, an invitation to a party, an inquiry about health, &c. 'In our business,' said a New York merchant, 'we use it continually. The other day two different men from Montreal wanted credit, and had no references; we said, "Very well; look out the goods, and we will see about it." Meanwhile we asked our friends in Montreal: 'Are Pump and Proser good for one hundred dollars each?" The answer was immediately returned, and we acted accordingly; probably much to our customers' surprise. The charge was a dollar for each message, distance about 500 miles, but much further by telegraph, as it has to go a round to avoid the water.'

A considerable portion of American telegraph was put up slightly at first, and was often destroyed by storms. Now it is made with heavier wire, on posts from eight to twelve inches diameter. The lines cross the Hudson suspended from the top

of a very high pole on each side, placed on the top of the hills. The wire goes over at one stretch; the distance about a mile, but still hanging high enough in the centre to allow the tallest ships to pass under it.

It was estimated that in 1850 there were 11,000 miles of telegraph at work in the United States. In 1853, the length was set down as 20,000 miles in the United States, and 3000 in British America. A large measure of amalgamation has been going on between the several American telegraph companies. After a period of intense competition and small profits, two of the New York companies combined; this proving successful, four others joined them, and formed together the *Western Union* Company; then four other companies made with them a working agreement, which has turned out well for them and for the public. In 1861, it was calculated that 50,000 miles were at work in the States; and by 1866 the length had increased enormously. A great feat was performed on one particular day in 1865, when a telegram was sent direct from New York to San Francisco, a distance of 4000 miles. To the credit of the Americans, they were the first to introduce the wonderful system of newspaper telegrams. Several newspapers clubbed together, and contracted with telegraphic agents for the supply of news from every part of the Union, the news being available to all the papers alike. At the present time, much more is done in this way in America than in England, owing to less clashing of interests and to lower charges.

Thus it is that, nearly all over the world, the lightning messenger is telling his tale. Even in 1862, it was supposed that 200,000 miles of line were at work, in all countries and all climes; and it is certain that a stupendous addition was made to the length between that year and 1866.

§ VIII. OCEAN-CABLE TELEGRAPHS.

At length we come to that which is, perhaps, the most wonderful of all these wonderful manifestations of electric agency—the *submarine telegraph*, a line of thought beneath the ocean.

The discovery of the fact that the moisture contained in the earth will convey the return current, and thereby complete the electric circuit, was virtually the beginning of submarine telegraphy. Even so far back as the beginning of the present century, Aldini succeeded in sending a current from bank to bank of Calais harbour, through the sea, after it had passed in the opposite direction through a wire elevated on the masts of boats. He also sent a current along the shore, the sea completing the circuit. The use of better-planned apparatus, however, was necessary to the due development of the principle. In 1842, Lieutenant Wright and Mr Bain sent electric impulses through the water of the Serpentine. Mr Wheatstone laid down an electric wire from King's College to the Shot Tower nearly opposite, and found that the water of the Thames sufficed to complete the circuit. A Jersey newspaper, in 1844, was bold enough to suggest the laying down of a telegraphic wire, covered by some insulating substance, in the sea, from Southampton to the Channel Islands; the idea was regarded as extravagant at that time, but subsequent experience has shewn that it was perfectly legitimate. In 1845, an American newspaper, bolder still, predicted that the Atlantic would one day be spanned by an electric wire, to interchange thoughts between Americans and Englishmen. Then came the actual submarine line in Portsmouth harbour, laid down in 1847; and so entirely successful was this, that projects began to be formed for similar

wires or cables from Dover to Calais, from Holyhead to Dublin, and from Marseilles to Algiers. In America, after ascertaining that gutta percha seems to be a better insulator for the wire than india-rubber, submarine or sub-river telegraphs were successfully laid in the Hudson river, from New York to Jersey City.

Dover and Calais, the white-cliff representatives of England and France on the opposite sides of the Channel, manifested the importance of the electro-telegraphic system in 1850. On the 28th of August in that year, after certain preliminary experiments had been tried, the *Goliah* steamer started from Dover with a huge reel on her deck, containing 25 miles of wire coated with gutta percha, which was slowly unwound and submerged as she left the land. A horse-box was set up on the beach, to serve as a temporary office for the instruments and operators; from which the wire was led through a leaden pipe to some distance beyond low-water mark, as a measure of protection in a part the most exposed. A line of buoys marked the track of the steamer; she travelled about four miles an hour, and the wire was gradually sunk at the same rate by means of heavy weights attached at regular intervals. A powerful set of batteries had been provided: as one of the objects was, if possible, to work Brett's printing telegraph; and when the steamer had made good a portion of her voyage, the communication was established, and words were printed at the instrument on board the vessel—imperfectly, it is true; but the fact once verified, the perfecting became matter of detail. The needle-instrument played freely, and in the evening its signals shewed that the voyage had terminated successfully. A message flashed from under the sea by the opposite party announced, 'We are all safe at Cape Grisnez,' with the inquiry added, 'How are you?' Thus the international communication was complete; but it was soon interrupted by the breaking of the wire, which was too weak to withstand the action of the water and friction on a rocky bottom. A *Submarine Telegraph* Company, which had undertaken this work, nothing daunted, at once set about preparations

to re-establish the connection, on a scale calculated to obviate the risk of accident. The wires, four in number, were enclosed in a cable several inches in circumference, and from twenty to twenty-five miles in length. Each wire was separately enveloped in gutta percha; a similar coating encircled all four; then came a binding of yarn dipped in melted tar and tallow; and then a tight spiral sheathing of ten galvanised iron wires. This formidable cable, weighing no less than 180 tons, was submerged in the autumn of 1851, from the South Foreland to Sangatte, near Calais, the one end being placed in connection with the English land-lines, and the other with those of France. At first this submarine telegraph was used only for the transmission of Stock Exchange intelligence; but on the 21st November, the *Times* reported Paris political news so promptly as to shew that a great power was at once developed. The effect was marvellous. Before the year 1852 was far advanced, London was placed in direct telegraphic communication (at a definite tariff of charge per telegram) with nearly all the chief cities of continental Europe, through the medium of this one Dover and Calais cable. Ireland was linked to England in the same year by a marine cable submerged from Holyhead to Howth. Holyhead surprised itself by *firing off a cannon at Howth!* The feat was managed thus. When the *Britannia*, bearing the cable, arrived at Howth safely, the end of the cable was put in connection with a loaded cannon on board; an electric message was sent through the cable, 65 miles long, giving the word 'fire;' Holyhead *did* fire, by sending a pulsation through the cable, and the cannon went off.

Cable after cable was submerged in various seas, as soon as the success of the method had been so completely shewn. Submarine telegraph companies began to spring up in considerable number, while one or two greater companies undertook the laying of many cables each. Portpatrick, in Scotland, to Donaghadee, in Ireland; the Mull of Cantyre to Fairhead; the Suffolk coast to the Holland coast; Genoa to Corsica; Corsica to Sardinia; Sardinia to Sicily; Sicily to Africa—all were

routes for which plans had been laid before the end of the year 1852. During 1853 and 1854, these and several other lines were finished; and then in 1855 came those unprecedented Crimean cables which told us how our poor fellows were getting on outside Sebastopol. This was very remarkable work, certainly. A thin cable, a mere cord of gutta percha, with one copper wire in the middle, was submerged in the Black Sea, from Varna in Turkey to Balaklava in the Crimea, a distance of 350 miles, with a subsidiary line of a few miles from Balaklava round to Eupatoria. The slender cord lasted in working-order only a year or so; yet it rendered an incalculable amount of service, by conveying messages direct from the War-office in Pall Mall to the camp outside Sebastopol. This, of course, involved the completion of the land-wires through European Turkey.

By the year 1857, the Ionian Islands and Africa were connected by submerged cables with Sardinia, and so with France and Western Europe. Then, in 1858, the commerce of Europe was aided by the laying down of two cables from England to Holland and to Hanover; and electricians had the excitement connected with the laying of the first Atlantic cable—an achievement to be fully described presently. And then did England unite herself electrically with Denmark, with the Isle of Man, and with Boulogne, in 1859; and Sweden with Gothland, Greece with the Greek islands, Italy with Turkey, Jersey with France, and Spain with Africa. In this year, too, was begun that costly but unfortunate Red Sea and India cable, 3800 miles long, extending from Suez down to Aden, and so across the ocean to Kurrachee, at the mouth of the Indus. Scarcely had the year 1860 seen the finish of this cable, when breakages and disasters began, so numerous and so frequently repeated, that the cable brought very few telegrams, indeed, from the distant East to Egypt. To complete the chain from India to Europe, numerous cables were submerged in various directions in the Mediterranean in 1859, 1860, and 1861—now from Greece to Syra, now from Syra to Candia, now from Candia to Alexandria, now from Malta to Alexandria. The

last of these, 1500 miles long, has been the most successful of all the great ocean cables yet constructed; to the year 1866, it has continued to be the chief means of informing our newspapers and politicians of the arrival at Suez of the mail-steamers from India, China, and Australia. A clever scientific achievement was carried out with the France and Algiers cable in 1860; when thirteen miles out at sea, 1250 fathoms of cable were fished up from the ocean-bed, a fault cut out, and the cable relaid.

To enumerate all the telegraphic cables submerged in 1862 and the four following years would be to give the history of six thousand miles of line, some successful, some disastrous. Spain, Italy, France, Turkey, Greece, England, Holland, Denmark, Sweden—all took part in linking the continent and the various islands of Europe by cables sunk in the German Ocean, the Irish Sea, the English Channel, the Baltic, the Black Sea, the Adriatic, and the Mediterranean. A grander work than any of these, perhaps, was the Persian Gulf and India cable, finished and set to work in 1865. Land-wires extend from the European system through Asiatic Turkey, Mesopotamia, and Persia, to the head of the Persian Gulf at Bassora; a cable then extends down the gulf to the Indian Ocean, and so on to Kurrachee. It is understood that the submerged portion of this line works better than the land portion, which is sadly neglected during its passage among the semi-barbarous tribes inhabiting the banks of the Tigris and Euphrates. Still, it *does* work, and telegrams are now interchanged between London and India.

The day has not yet arrived for linking Australia with Asia by cable, yet it is one of the achievements fairly to be looked forward to in the future. From North Australia to some of the islands in the Indian seas, and from thence to Singapore, electric cables will probably be submerged before many years have passed. At present, the mail-steamers from Australia touch at Point de Galle in Ceylon, and transmit telegrams to England from thence, if the India and Persian Gulf lines are in working-

order; if not, the telegram cannot be sent until the steamer arrives at Suez, seeing that the Red Sea cable is no longer in working-order. As one example of the usefulness of the cable from Kurrachee to the Persian Gulf, it may be mentioned that a mail-steamer, leaving Melbourne on September 25, 1866, reached Point de Galle on October 22, and flashed a telegram at once to London, thus giving us news from Australia in less than a calendar month.

In the South Atlantic, nothing has yet been done in the way of submarine telegraphy; but Spain, in 1865, conceded to a company the privilege of submerging cables to connect Cuba with North, South, and Central America. The Pacific, from north to south, is without any such aids to commerce. The scheme, however, mentioned in a former section, of connecting America with Asia by telegraph, will comprise the submersion of a cable across Behring's Strait, and another across the Sea of Okhotsk.

Reuter's Telegrams, a mystery to most people, are connected with many submarine as well as many land lines. Some years ago Mr Reuter organised a plan for collecting telegraphic information from various parts of the continent, arranging it in a London office, and then supplying it to newspapers and commercial firms on certain stipulated terms. It is an adaptation of a plan which has long been acted on in America, and is found to be valuable both to the newspaper proprietors and to the commercial public. Mr Reuter has not hitherto been the owner of telegraphs, land or sea; he makes contracts with the owners, and, in fact, buys telegrams from them. 'Reuter's Telegraph Company,' however, established in 1865, took over all Mr Reuter's business, and, at the same time, undertook the ownership and submersion of a new cable from Hanover to England —considered to be one of the finest ever yet constructed.

§ IX. THE ATLANTIC TELEGRAPH: EARLY ATTEMPTS.

We now approach so important and deeply interesting a series of episodes in the history of electro-telegraphy, as to require a fuller mode of treatment than was necessary in the last section. Never in the history of the application of science to the arts have more wonderful results been obtained, or more singular difficulties surmounted, than in the Atlantic oceanic cable laying between 1857 and 1866.

There were several submarine cables at work before the magnificent idea arose of submerging one beneath the whole breadth of the Atlantic. When it became known that electric telegraphic communication could be made across the Irish Sea to the west coast of Ireland; when it became known that similar communication could be made from the United States to Newfoundland—then did it become plain that, so far as an ocean cable is concerned, 1700 miles from Ireland to Newfoundland would suffice, instead of 3000 miles from Liverpool to New York: land-wires and short cables supplying the rest. As to the possibility of insulating a wire in a long submarine cable, Professor Morse expressed a strong opinion in the affirmative, so far back as the year 1843; but it was not until about the time of our first Great Exhibition that the Atlantic project began seriously to occupy men's thoughts. In 1851 a plan was formed for connecting Newfoundland, Prince Edward Island, and New Brunswick with the United States by wires and cables; in association with a projected line of steamers from Newfoundland to Ireland. The legislature of that colony gave encouragement to the project; and Mr Gisborne proceeded with the work in 1852—53. But financial troubles overtook the company, and

the works were suspended. In 1854 Mr Gisborne and Mr Cyrus Field discussed together, not only the means for finishing the British-American wires and cables, but a mighty scheme for spanning the Ocean itself. There has been a little discussion on both sides of the Atlantic concerning the precise person to whom honour is due as the originator of the scheme; but in truth there was no *one* such person, any more than there was *one* inventor of the steam-boat; many ingenious minds combined in various ways to work out a grand result.

Lieutenant Maury and Professor Morse were taken into council by Mr Gisborne and Mr Field; and various naval officers were consulted touching the soundings, ocean-bed, winds, tides, and currents of the Atlantic. Lieutenant Maury inferred, from a mass of observations that had been obtained, that there is a kind of plateau or elevated plain at the bottom of the Atlantic, between Ireland and Newfoundland, highly favourable as a resting-place for a telegraphic cable: the surface being composed of a layer of shelly fragments as fine as sand. He at once gave it the name of the *Telegraphic Plateau*, and declared it to be the only practicable line of route for a sub-Atlantic cable. Mr Field organised, among the monied men of New York, a 'New York, Newfoundland, and London Telegraph Company;' and great powers, almost amounting to a monopoly, were granted to this company by the legislatures of the several British-American colonies affected. The property and rights of the old company were bought up, and the works recommenced. In 1855 Mr Field came to England, and consulted Mr Brunel, Mr (afterwards Sir Charles) Bright, Mr Brett, Mr Whitehouse, and other experienced persons, respecting the great cable and all that pertained to it.

The year 1856 came, and found Mr Field and his company still engaged in laying down cables to connect Newfoundland, Prince Edward Island, and Nova Scotia. A grand experiment was made for him one night by the English and Irish Magnetic Telegraph Company; they sent messages through 2000 miles of underground wire, and shewed that the force was quite adequate

to that amazing amount of work. In order to bring greater monetary power to bear on the project, English capitalists were invited to join; and at length was born, towards the close of the year (1856), the *Atlantic Telegraph Company*. There were superb notions among the promoters; nothing less than £1000 to be received; the capital sum to be £350,000, in 350 shares of £1000 each. So favourably was the scheme viewed, that money was abundantly forthcoming. As it would not be wise to make the cable bear any near proportion in length to the distance from Ireland to Newfoundland: in other words, as it was necessary to provide abundantly for 'slack,' or twistings and deviations—it was resolved to construct 2500 miles, although the distance is barely 1700. The embedding of the wires in the insulating gutta percha was intrusted to the Gutta-Percha Company; the finishing of the cable was undertaken by Messrs Newall and Messrs Glass and Elliott, in equal proportions. The cost was to be about £90 per mile, and the cable was to be ready by the ensuing midsummer.

A busy year indeed was 1857; for the capital was to be paid up and spent, the legislative privileges obtained, the cable manufactured, and the submersion completed. An act of parliament was passed; and the British government signed an agreement to pay £14,000 a year (4 per cent. on the capital) for government messages, to be lessened to £10,000 a year when the net profits of the company reached 6 per cent.; to pay this subsidy for 25 years; and to assist with Admiralty ships in making soundings and laying the cable. The United States government, after some opposition in Congress, granted exactly similar terms to the company. Thus the encourgements afforded were really very great, and seemed to augur enormous profits to the company.

Let us see of what the cable consisted, and how it was made. Fifty or sixty kinds were tried; and it was not until a vast number of experiments had been gone through that the final form and dimensions were determined. A cable too bulky would require too much ship-room to convey it; too heavy, it

would be in danger of severance by its own weight during suspension before touching the ocean-bed; too light, it would be at the mercy of the waves and currents, liable to be carried about in zigzag curves wholly beyond the power of the engineer to control or measure; too weak, it would not bear the requisite weight and strain; too rigid, it would not wind readily round the drums employed in the submersion, nor would it conform itself easily to the irregularities of the ocean-bed. All these matters had to be considered, and a balance of advantages secured. The cable, as eventually decided on, consisted of seven fine copper wires, twisted together into a neat cord, six round one; this formed the *conductor*, about $\frac{1}{12}$th-inch thick, and weighing 107 pounds per mile. Outside this were three layers of gutta percha, bringing the diameter to about $\frac{3}{8}$th inch, and forming with the conductor the *core*. This core was covered with hempen twine, saturated with pitch, tar, bees-wax, and boiled linseed oil; and outside it was the *sheath* of 18 strands, each consisting of 7 iron wires coiled tightly around each other, or rather six around one. Thus the cable was really a very complex structure. Although only $\frac{6}{10}$-inch diameter (less than the size of a farthing), it contained 7 copper wires and 126 iron wires. The weight was just about one ton per mile.

The manufacture of the cable called forth all the skill and resources of the eminent firms engaged upon it. To make the copper conductor, one wire was dragged downwards through a hole in a circular table, while the other six wires, each uncoiling from a revolving drum, were twisted spirally round it by the rapid rotation of the table itself. To coat the copper conductor with an insulating substance, gutta percha was rasped, macerated, churned, washed, boiled, sifted, squeezed, and kneaded to a great degree of fineness and smoothness; it was forced by hydraulic pressure through a die, which also had the copper conductor running through it; and the two came out together, the copper in the midst of a cord of gutta percha. A second and a third drawing through dies thickened the layer of insulating substance. The core was made in pieces two miles long;

and fifty of these, after testing and examination, were wound round several drums, and conveyed from the Gutta-percha Works to the Wire-cable Works. Here, by revolving drums and twisting machines, the core was coated with a layer of hempen yarn; while the two-mile pieces were joined end to end as fast as this process advanced. Revolving bobbins and drums twisted seven iron wires into a strand, and then twisted eighteen of these strands round the core; the core rose up through the centre of a whirling table, and the strands coiled themselves around it. The seven small wires to form each of the eighteen strands were deemed better than one wire of equal total size, for safety in case of partial breakage; and the same reasoning led to the employment of seven small copper wires instead of one thicker wire for the conductor. As there were 133 wires in the cable, all told, and as most of them were twisted in a spiral during the progress of manufacture, it resulted that there were more than 330,000 miles of wire in all—enough to reach from the Earth to the Moon, with a good surplus for 'slack.' The finished cable was drawn through a mixture of melted pitch and tar, and coiled in large masses until shipped.

Thus was the manufacture carried on to completion; and the engineers who were to undertake the submersion then set their brains to work.

There was no ship in the world at that time (the *Great Eastern* being unfinished) that could carry out the whole 2500 miles of cable; and therefore the English government lent the *Agamemnon*, and the American government the *Niagara*, to divide the work. The one ship received its half of the cable at Greenwich, the other at Birkenhead. The *Agamemnon* had space enough in the hold for her share of the cable, 1250 miles, in one single coil; but the *Niagara* was driven to the adoption of three coils, placed at different parts of the ship.

Valentia, in county Kerry, the most westerly port in Europe, was selected as the point of departure. It was agreed that the two ships should sail side by side, and the *Niagara* first pay out her half of the cable, to be followed by the *Agamemnon*

similarly submerging the second half: a junction or splice being made in mid-ocean, half-way between Valentia and Newfoundland.

A busy day was the 7th of August 1857. Six steamers were assembled in the usually quiet harbour of Valentia—the *Agamemnon* and the *Niagara* carrying the two halves of the cable; the *Leopard*, *Susquehanna*, *Willing Mind*, and *Advice* ready to afford assistance. The shore-end of the cable was landed, and received with some ceremony by the Lord Lieutenant of Ireland in a temporary telegraph-house on the beach. Off the ships went, the *Niagara* submerging her half of the cable. The apparatus for effecting this was strong and yet nicely adjusted. Uncoiling from the hold of the ship, the cable passed round a central block or core, wound round and among a series of grooved sheaves, passed over another sheave overhanging the stern of the ship, and so plunged into the sea. The paying-out, or departing of the cable from the ship was at a speed depending on the ship's speed, which was kept low and steady. Electric currents were repeatedly sent through the whole length of cable, to test whether the insulation was complete; and signalmen were on the watch to see that all went well and steadily. Five miles of auxiliary iron cable rope (not electric) were provided on board, to be used in case the electric cable were suddenly endangered by a storm or any other calamity; the true cable would in such case be cut, after being attached to the auxiliary wire rope, and allowed to swing at leisure until the storm were over.

The chapter of misfortunes soon commenced. When only four miles of the shore-end of the cable had been paid out, an entanglement of some of the machinery led to a breakage, and the *Niagara* had to lie-to while a splice was made. On the 8th, at noon, the ships had proceeded so far as to pay out 40 miles of cable; 85 miles by midnight; 136 miles by noon on the 9th; 189 by midnight; 255 by noon on the 10th. By noon on the 11th, however, the engineer, finding that they had expended 335 nautical miles, or 380 statute miles of cable in a straight-

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line distance of only 280 miles, began to fear that the slack or zigzag was too great; he altered the paying-out machinery; this was done unskilfully, and snap went the cable in 2000 fathoms water. It was the second accident, but it proved to be conclusive; for the scientific men on board, even if they had succeeded in fishing up the end of the cable from a profound depth of $2\frac{1}{4}$ miles, began to feel that the quantity of cable in store was not sufficient. They resolved to abandon the enterprise for the present, and return to Ireland. Deep was the mortification. On the eve of departure, the late Earl of Carlisle, as Lord Lieutenant of Ireland, had expatiated on the fervent hope of establishing 'a new material link between the old world and the new. Moral links there have been, links of race, links of commerce, links of friendship, links of literature, links of glory; but this, our new link, instead of superseding and supplanting the old ones, is to give them a life and intensity they never had before. The link which is now to connect us, like the insect in a couplet of our poet,

> "While exquisitely fine,
> Feels at each thread, and moves along the line!"'

And his lordship spoke as if even wars would be impossible when a thread of instantaneous thought was stretched between the old world and the new. 'What excuse would there be for misunderstanding? What justification would there be for war, when the disarming message, when the full explanation, when the genial and healing counsel may be wafted even across the mighty Atlantic, quicker than the sunbeam's path and the lightning flash?' Alas! nations do not always wait for 'justification for war' before they plunge into it—as recent events have too well shewn.

Mr Field at once started off in one of the attendant steamers to London, while the other ships returned, not to Ireland, but to Plymouth. The unused portion of the unfortunate cable, some 2170 miles long, together with 53 miles of thick shore-end, were removed from the ships, and deposited in tanks in the

Government Steam-yard at Keyham, near Devonport; and so ended the voyage. Judging from subsequent experience, there seems no reason to doubt that the supply of cable would have been sufficient, provided the two ships had maintained anything like a steady and uniform course; but probably those on board saw sufficient reason to doubt the maintenance of this steadiness, and deemed it wise to submit to temporary discomfiture rather than risk the whole cable.

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§ X. TEMPORARY SUCCESS IN 1858.

WHAT was next to be done? Were the promoters to sit down quietly under the loss of three or four hundred thousand pounds sterling. They speedily decided to be up and doing. Mr Charles Bright, their electrical engineer, in a report to the directors, said: 'I do not perceive in our present position any reason for discouragement; but I have, on the contrary, a greater confidence than ever in the undertaking. It has been proved beyond a doubt that no obstacle exists to prevent our ultimate success; and I see clearly how every difficulty which has presented itself in this voyage can be effectually dealt with in the next. The cable has been laid at the expected rate in the great depths; its electrical working through the entire length has been most satisfactorily accomplished; while the portion laid actually improved in efficiency in being submerged, from the low temperature of the water, and the close compression of the texture of the gutta percha; the structure of the cable has answered every expectation that I had formed of it; and if it were now necessary to construct another line, I should not recommend any alteration from the present cable.' The directors took heart. They raised additional capital; they ordered from Messrs Glass and Elliott 900 miles more cable; they adopted an improvement in the paying-out apparatus, constructed

under the care of some of our best engineers; they availed themselves of Mr Appold's self-regulating break, to check the rate at which the machinery revolved; and they obtained from the British and United States governments promises of assistance in ships in the summer of 1858.

And so the summer came. The cable at Devonport (it was afterwards known) suffered in electric capability during the many months in which it was stowed away; but this unfortunate fact was not known at the time. The *Agamemnon* and *Niagara*, with the old and new portions of cable on board, steamed out of Plymouth, and proceeded to their place of rendezvous. This was not Valentia; for a new plan had been formed. It was now decided that, instead of beginning at one end and proceeding steadily to the other, the two ships should steam out together to mid-ocean, where the two cables would be spliced; then the *Agamemnon* would steam slowly eastward to Valentia, and the *Niagara* westward to Newfoundland, paying out the cable as they went.

It was a bright and brilliant day when the ships set forth on the 10th of June; but untoward weather set in within a few hours, and the steamers were lashed by a terrible storm for seven consecutive days. It was not until the 25th, more than a fortnight after the starting, that the ships succeeded in reaching the appointed locality, in lat 52° 2′ N., long. 33° 18′ W.; with the enormous weight on board, they had rolled fearfully, and lives as well as cable were more than once in great danger. One end of the cable from one ship was spliced to an end of the other from the second ship—an operation of no small difficulty in a stormy ocean. This splicing is effected by laying bare the copper wire for a given length at each end, filing it to a given angle or slope, soldering together two such filed ends, binding and bracing them with fine wire, applying layer after layer of gutta percha, alternating these with the bituminous mixture known as Chatterton's compound, and again twisting the outer iron wires round the coil. The 'Wire Squadron,' as the sailors called it, then separated; the *Agamemnon*

steaming towards Valentia, the *Niagara* towards Newfoundland. On the 26th they began the submerging, but had not proceeded far when the cable broke. Another splice, and another start on the 28th; when lo! after 111 miles had been paid out by the *Niagara*, and 118 miles by the companion-ship, a double snap took place on the 29th; and there lay 144 miles of cable at the bottom of the ocean, wholly severed from the other portions, and the operations rendered worse than useless.

What was to be done? To return to England or Ireland and consult the directors. The *Agamemnon* steamed off to Cork, which she reached on the 12th of July. As soon as official communications could be held, it was at once resolved—as there was still cable enough and summer weather enough—to try again.

Then commenced the third Atlantic telegraph expedition—that is, the second of the year 1858. Off they started again, and on the 29th of July the two great ships spliced their two portions of cable in mid-ocean. This time, the splice was dropped in lat. 52° 10′, long. 32° 29′. All proceeded now so surprisingly well, that the officials could hardly credit their senses. Day after day the operations went steadily on, paying out eastward by one ship, westward by the other—265 miles on the 30th, 540 by the evening of the 31st, 884 by the 1st of August, 1256 miles by the 2d, about 1550 by the 3d, 1854 by the 4th, and 2022 by the 5th. How it happened that they could lay so much as nearly 400 miles in one day was because each ship did half that quantity—one eastward and the other westward. So well had the work been timed, that the ships arrived at the two islands on the same day, the one at Valentia and the other at Newfoundland.

The first lightning message, the first electric telegram, was flashed across the Atlantic on the 6th of August 1858. The *Agamemnon* and the *Niagara* spoke to each other, telling what they had done in landing the two shore-ends of the cable; and then Valentia sent word to London, and Newfoundland to the United States and Canada. England was delighted, but

America was almost wild with joy. Mr Cyrus Field, in Trinity Bay, Newfoundland, sent messages to the New York Associated Press and to President Buchanan; the telegraph company in London sent to congratulate the telegraph company at Newfoundland; and the Lord Mayor of London interchanged compliments with the Mayor of New York. But the most majestic messages were between Queen Victoria and the President of the United States, on 16th August. The one message was to the following effect:

'*To the President of the United States, Washington.*

'The Queen desires to congratulate the President on the successful completion of this great international work, in which the Queen has taken the deepest interest.

'The Queen is convinced that the President will join with her in fervently hoping that the electric cable which now connects Great Britain with the United States will prove an additional link between the nations whose friendship is founded upon their common interest and reciprocal esteem.

'The Queen has much pleasure in communicating with the President, and renewing to him her wishes for the prosperity of the United States.'

In sixty-seven minutes this message was transmitted from London to Washington through the ocean cable and land wires; and in about the same time the President's message was transmitted:

'*To Her Majesty Victoria, Queen of Great Britain.*

'The President cordially reciprocates the congratulations of Her Majesty the Queen on the success of the great international enterprise accomplished by the science, skill, and indomitable energy of the two countries. It is a triumph more glorious, because far more useful to mankind, than was ever won by conqueror on the field of battle.

'May the Atlantic telegraph, under the blessing of Heaven,

prove to be a bond of perpetual peace and friendship between the kindred nations, and an instrument destined by Divine Providence to diffuse religion, civilisation, liberty, and law throughout the world. In this view will not all nations of Christendom spontaneously unite in the declaration that it shall be for ever neutral, and that its communications shall be held sacred in passing to their places of destination, even in the midst of hostilities?'

Whether the Atlantic telegraph would have kept the two nations in perpetual friendliness, and whether it would be regarded as neutral in war by all civilised nations, the cable of 1858 was not destined to shew. It speedily failed. The transmitted impulses became gradually weak, as if its strength were overpowered by too much electric energy. At last, on the 1st of September, it ceased to speak, after having conveyed 1474 words in 129 messages from England to America, and 2884 words in 271 messages from America to England.

Down went the company's shares in the market, and deep was the mortification of everybody concerned. Scientific men inquired into the matter by every test they could apply. There was the cable lying quietly along the bottom of the ocean; but it refused to convey messages, refused to give passage to the swift-moving current of electricity. The decision arrived at was, that the cable had been manufactured too hastily; that it must have been defective while on shipboard; that the strain upon it was too great and too unequal while being paid out; and that it had been injured by so many coilings and uncoilings in two successive years. Half a million of money was gone, irretrievably gone, unless the cable could be picked up and repaired; and the directors were not sanguine enough to say much to the disappointed shareholders on this point. Nevertheless, there were men who remembered that the very last word which the cable flashed from Europe to America was '*Forward*'—a word of good omen.

§ XI. PREPARING FOR ANOTHER ATTEMPT: 1859—1864.

LITTLE is there to tell concerning Atlantic telegraphy during 1859 and the five following years. When engineers have no definite plans, directors no capital, and the public little or no hope, joint-stock enterprises have not a brilliant time of it. A few words in reference to each year's proceedings will suffice for the present purpose.

The year 1859 presented little beyond discussion and controversy as to the cause of the electric failure of the cable: it was still believed to be unbroken. Advocates came forward with a scheme for a new Atlantic route, intended to afford several land resting-points between England and America, and thus not trust to one submarine cable of so great length. Of this scheme we shall speak in another section. Meanwhile, the original Atlantic Company reopened negotiations with the government, with a view to obtain such an increased subsidy as would induce capitalists to come to the rescue. A provisional arrangement was made, to the effect that the government would guarantee 8 per cent. on a *new* capital of £600,000 for twenty-five years, and pay £20,000 a year for government telegrams. Of course, this was conditional on the raising of the money, the manufacture and submersion of the cable, and the success of all the working details.

In 1860, as in the preceding year, money and science were the two matters which occupied the attention of the company. As to money, they could get little. Even the tempting 8 per cent. subsidy failed to restore confidence to the public, so deep had been the general disappointment. The directors appointed a committee of very able men to examine and report upon all

the circumstances that bore in a scientific or practical way on submarine telegraphy. Mr Fairbairn, Professor Wheatstone, Mr Bidder, Messrs Edwin and Latimer Clark, Mr Varley, and Captain Galton were men who could not easily be excelled in their several departments; and the directors could hardly do better, it would seem, than consult such savans. In the same year the directors sent out Captain Kell and Mr Varley to Newfoundland, to endeavour to recover some portion of the cable. They only succeeded in fishing up five miles of it, and found that the sea-bed was much rougher and more uneven than had been supposed. The recovered portion was still, however, electrically good, and no adequate reason appeared why the cable generally had failed.

The year 1862 found the scientific committee very busy with their investigations and experiments. The results were published from time to time, and were taken into consideration by the directors. An attempt was made to fish up another portion of the unlucky cable at the Valentia end; but only a little was effected, not sufficient to defray the cost.

In 1863, the prospects began to brighten a little. The directors announced that Messrs Glass and Elliott would make and submerge, for £700,000, a new cable of the kind proposed by the scientific committee, with a certain conditional ratio of payment, according as the attempt should succeed or fail. Mr Cyrus Field went to New York to interest American capitalists in the matter, holding out what seemed to some persons at that time hopes that the new cable would realise 40 per cent. per annum dividend on the capital required to construct it. In London, another scientific committee confirmed the decision of the former, and decided on the kind of cable which was eventually adopted.

Those who are fond of tracing coincidences may find singular materials for so doing in the chequered fortunes or misfortunes of two noble enterprises in 1859 and the five following years—the *Great Eastern* steam-ship and the Atlantic cable. Both were unequalled of their kind; both had cost a vast deal more money

than had at first been intended; both had suffered a series of mishaps; and both were held up commercially by new capital provided from time to time between 1859 and 1864. Singular, too, that their fortunes now brought them intimately together, in a way presently to be told.

The year 1864 was a busy one. Capitalists, encouraged by the confidence of all those who had been practically concerned with the former cable, came forward with the money, and took the shares. The Gutta Percha Company, who had made the core, and Messrs Glass and Elliott, who had made the sheath, now joined their fortunes, and became the 'Telegraph Construction and Maintenance Company.' They took the contract for making and submerging the new cable, to be paid partly in shares and partly in cash, and the price to vary according as the enterprise succeeded or failed. As a means of avoiding the evils that had arisen from placing two halves of the cable in different ships, they resolved to charter the only ship in the world that could contain the entire cable without destroying her sailing capabilities—the *Great Eastern*. In order that the responsibility of the whole affair should be clearly defined, the ship was chartered by, and her owners made immediately responsible to, those who were to make and submerge the cable—not those who were eventually to pay for it.

Let us see in what particular this new cable differed from the old one. Instead of being 6-10ths of an inch thick, it was 11-10ths; instead of being sheathed with 18 iron wires twisted into a coil, it was sheathed with 10; instead of each of these being a strand of seven smaller wires, each was one thick wire; instead of a breaking strain of $3\frac{1}{4}$ tons, the whole cable would bear $7\frac{3}{4}$ tons; instead of weighing about 1 ton per mile in air, it weighed $1\frac{3}{4}$ tons; instead of weighing 13·4 cwts. per mile in water, it weighed 14 cwts.; instead of being able to bear 4·85 times its own weight in water, it would bear 11 times; and instead of having 260 lbs. of gutta percha per mile outside the copper conductor, it had 400 lbs. The seven copper wires which collectively formed the conductor, were each about $\frac{1}{20}$th

inch thick, and together weighed 300 lbs. per mile. The sheath wires had the thickness known in the trade as 'No. 13.' As to the processes of making, they differed very little from those already described. The centre copper wire of the conductor, after being coated with gutta percha melted in hot Stockholm tar, had the six other wires coiled around it into a compact mass. The conductor, thus made, was coated with the mixture just named—constituting 'Chatterton's compound'—then with pure gutta percha; then with another layer of compound; then another of gutta percha; and so on, until four coatings of the one alternated with four of the other. The core was passed through a die in the application of each gutta-percha coating, to make it a smooth, firm, uniform, solid cylinder. This finished core or cord, weighing about 700 lbs. per mile, was tested in all sorts of ways during the manufacture, and was then conveyed in convenient lengths to the works at East Greenwich, where the ten stout iron wires were coiled around it. A layer of jute yarn, tanned in catechu, was placed between the core and the sheath; and each of the ten wires of the sheath was, before being used, covered with a layer of tarred Manilla yarn. In this way there were gradually made 2300 miles of cable, weighing $1\frac{3}{4}$ tons per mile, making about 4100 tons—a truly mighty weight for any one ship to take out to a storm-tossed ocean! To prevent the cable from being injured by friction on the shallow beaches at Valentia and Newfoundland, 27 miles of 'shore-end' were made, the thickest ever produced, being no less than $2\frac{1}{2}$ inches in diameter, and weighing 20 tons per mile.

In naming these quantities, relating to the thicknesses of the cable, we may remark that the word 'cable' greatly deceives many persons as to the real dimensions of the rope produced. A cable is a ponderous production for holding anchors, a rope sometimes as much as 8 inches in diameter, or 25 inches in circumference. True, such cables are not now often made, seeing that the larger kinds are manufactured of iron chain instead of twisted hemp; nevertheless, a hempen cable is still

the largest kind of hempen rope. No telegraphic cable ever yet made approaches anything near the thickness of a ship's cable. The shore-ends, just spoken of as so ponderous, are not thicker than a lady's wrist; the main cable preparing for 1865 was barely equal in diameter to a florin; the cable laid from Malta to Alexandria was less than the size of a halfpenny; the Atlantic cable of 1858 did not exceed the diameter of a farthing; while the Crimean cable of 1855, which stretched across the Black Sea from Varna to Balaklava, and which rendered such inestimable service in conveying messages to and from our army engaged in the Russian War, was a mere cord, more like a wax-taper than anything else. It matters not much in effect, yet it would give general readers a much more correct idea if a better name than telegraphic 'cable' had been originally adopted.

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§ XII. THE CABLE FAILURE OF 1865.

THE time for another grand attempt was near at hand. All the companies worked with heart and hope during the winter of 1864—65, bringing up their several plans and organisations to the requisite degree of completeness. They had every motive for doing their best. The many hundreds of thousands sterling already sunk would never be recovered unless another attempt were made; the manufacturers were deeply interested; the scientific men felt their pride a little touched; and the commercial world wished that 1865 might give them what 1858 had given—telegrams from the other side of the Atlantic.

There was much still to be done before these hopes could be practically realised. The *Great Eastern* had to be considerably altered in her interior arrangements to accommodate the immense coils of cable. Three circular tanks were fitted into her, mostly of half-inch and five-eighths iron, backed and

supported by massive timbers. The fore-hold tank was 51½ feet diameter by 20½ deep, and would hold 693 miles of cable; the after-hold tank, 58 feet diameter by 20½ deep, for 898 miles; and the midship tank about the same size. The united capacity was 2490 miles,* or 190 miles more than would really have to be conveyed. The government lent the *Iris* and the *Amethyst;* and these two ships were employed, month after month, in carrying portions of finished cable from East Greenwich to the Medway, where the *Great Eastern* was moored. Very carefully made and managed machinery was employed to transfer the cable from the water-filled tanks at East Greenwich to the *Iris* and *Amethyst*, and from those vessels to the water-filled tanks in the *Great Eastern.* The cable itself was made by January 1865, but it occupied from that time to June to get the whole of it spliced and properly coiled in the tanks of the mighty ship.

Who shall measure the sanguine hopes of joint-stock directors, or say when those hopes become extravagant? The company wanted more money; and in raising it by eight per cent. preference shares, they expressed a belief that those shares would be at *four hundred per cent. premium* by the end of July! The money was forthcoming, but not the fulfilment of the prediction.

Great was the joy when, on the 24th of May, the Prince of Wales sent a message of health-drinking or success-wishing through nearly the whole length of cable in the great ship; high was the admiration when, on the 24th of June, the *Great Eastern* steamed out of the Medway to the Nore, with 4600 tons of main

* In most of the accounts of these telegraphic achievements, there is sad confusion in the stated lengths, owing to a want of attention to the difference between a *statute* mile and a *nautical* mile—the one being 1760 yards and the other 2025 yards. Even the official descriptions often leave it in doubt which standard is meant. And in like manner in reference to the distance from Valentia to Newfoundland, it is given sometimes at 1640 miles and sometimes at 1834 miles (even in different pages of the same book)—a difference nearly analogous to that between a statute mile and a nautical mile.

and shore cable on board, 2000 tons of iron tank, and 7000 tons of coal; and warm were the parting greetings which were exchanged on the 15th of July, when the grand ship weighed anchor and started on her voyage. On the 17th, she came up with the *Caroline* steamer, freighted with the massive shore-cable; and the two steamed on to Ireland. The *Great Eastern* anchored in Bantry Bay until all was ready for her at Valentia, from the 19th till the 22d.

A little nook called Foilhummerum Bay was selected as the scene of operations. It is a cove in Valentia Harbour, about a mile long, and tapering in width from half a mile to a mere creek, having a sandy bottom, and bounded inland by high cliffs. On the cliff had been built a temporary wooden telegraph-house, full of apparatus of various kinds for testing the cable in connection with the land-wires. Along the beach, and up the face of the cliff, was dug a trench or trough, in which the thick shore-end of the cable was to be laid. What the peasantry in the neighbourhood thought of the scene, not even they themselves could say; they seem to have had a sort of vague idea that the cable was to carry them over to America, whither so many of their countrymen had emigrated.

Hitherto we have derived our information from various scientific sources; but now we must rely on Dr W. H. Russell, who, invited by the several companies, witnessed the whole of the subsequent operations. His vivid description is contained in a splendidly illustrated volume published by Messrs Day and Son, the coloured plates of which were engraved from drawings by Mr Dudley. We will present the results day by day, in a more condensed form.

July 21.—With the *Hawk*, *Caroline*, *Alexandria*, and *Advice*, at Foilhummerum, and the *Great Eastern*, *Terrible*, and *Sphinx* in Bantry Bay, a subsidiary 'earth cable' was carried down the face of the cliff, and in the trough along the beach to the sea.

July 22.—The *Caroline* being anchored a little way out, the great or shore cable was hauled out from her, and carried over twenty-five boats to the shore, and so up the cliff to the telegraph-

house. The Knight of Kerry, in the midst of a numerous assemblage at the house, welcomed the receipt of the extreme end of the cable, and expressed a belief that 'there never had been an undertaking in which, not to speak disparagingly of the commercial spirit and the great resources and strength of the land, that valuable spirit had been mixed up with so much that is of a higher nature, combining all the most noble sentiments of our minds, and the feelings intended for the most beneficial purposes, which are calculated to cement one universe, I may say, with another.' And then Sir Robert Peel, the Irish secretary, added: 'We are about to lay down, at the very bottom of the mighty Atlantic, which beats against your shore with everlasting pulsations, this silver-toned zone, to join the United Kingdom to America. Along that silver-toned zone, I trust, may pass words which will tend to promote the commerce and the interest of the two countries; and I am sure we will offer up our prayers for the success of an undertaking, to the accomplishment of which persevering industry and all the mechanical skill of the age have been brought to bear. Nothing has been wanting in human skill; and therefore, for the future, as now, let us trust that the hand of Divine Providence will be upon it; and that, as the great vessel is about to steam across the Atlantic, no mishaps or misfortunes may occur to imperil or obstruct the success of the work which has now been so happily commenced.' And then, at two o'clock, off went the *Caroline*, slowly and carefully paying out the bulky shore-end cable, finishing her work at a distance of 26 miles out, in 75 fathoms water.

July 23.—The *Great Eastern*, *Terrible*, and *Sphinx* had come round from Bantry Bay; and then was executed the operation of splicing the shore-cable with the main cable—this being done on board the *Caroline*. Everything being in readiness, the splice was dropped into the sea; and the *Great Eastern* started on her grand enterprise, exchanging hearty cheers with all the other vessels. The *personnel* of the ship had been carefully attended to. The Atlantic Telegraph Company were repre-

sented by Mr Cyrus Field, Mr Varley, and Professor W. Thomson; the Telegraph Construction and Maintenance Company, by M. de Sauty, Mr Canning, Mr Clifford, and Mr Willoughby Smith; and the Great Ship Company, by Mr Gooch, Captain Anderson, and Lieutenant Moriarty—each of these gentlemen having duties exactly defined, so as to obviate the possibility of conflicting responsibilities. Mr Glass remained at Foilhummerum, to superintend the operations at the telegraph-house. A plan had been agreed upon to exchange electric signals *every hour* between the ship and the shore, and to keep up an incessant system of electric testing night and day, in order to detect any the smallest interruption in the continuity of the current. A large number of persons were on board; but in order that the proceedings might not be interrupted by idlers and mere sight-seers, every person had some particular office to fill or duty to perform—Dr Russell that of historiographer or literary recorder.

July 24.—Troubles began very soon. At three in the morning, the delicate apparatus pointed to something wrong in the cable, when 84 miles out; guns were fired to signal the *Terrible* and *Sphinx* to stay their course; and the fires were lighted of two small steam-engines to work the pick-up apparatus. Where the fault lay, no one could tell; but the experienced electricians on board had their theories about it. Nothing could be done until the poor cable was hauled in again, yard after yard, until the faulty spot was discovered. It was delicate work. The cable was cut, and the end secured to a strong iron-wire rope; the ship was turned with her head to the east; the rope was transferred from the paying-out apparatus at the stern to the pick-up apparatus at the bows; and the ship steamed slowly back towards the Green Isle. Meanwhile, as the cable was not *quite* dumb, a message was sent to Mr Glass at Foilhummerum, requesting him to send out the *Hawk;* to which message he responded. Lat. 52° 2′, long. 12° 17′.

July 25.—There had not been much rest for the officials during the night; for they had to haul in mile after mile, at the

rate of a mile an hour, and did not know what tale the cable might have to tell them. The big ship picked up the cable as delicately as 'an elephant taking up a straw in its proboscis.' When ten miles had been hauled in, the injured part was discovered; the offender consisted of a piece of wire of the same kind as that used in the sheath, two inches long, bent in the middle, and forced through the gutta percha to the copper conductor. How it got there, no one could tell. Another silencing of the cable occurred on the same day; but the wonderful cord recovered its speech without another in-hauling. The splice was made, the mighty ship was turned with her head to the west, the pick-up machinery was abandoned, the paying-out machinery was resumed, the *Hawk* returned to Ireland with letters after a brief companionship, the *Terrible* signalled her congratulations that all was well, and the *Great Eastern* again steamed on slowly towards Newfoundland, paying out as she went. Lat. at noon, 51° 58′, long. 12° 11′; 66 miles straight distance, 74 miles paid out (which always greatly exceeded the distance actually run by the ship, and still more the straight-line distance as measured on a chart).

July 26.—Steadily the mighty ship went on, caring little for the waves of the Atlantic; while the *Terrible* and *Sphinx* rolled and pitched considerably, in their assigned duty of taking soundings. The ships had passed over a grand submarine mountain slope, the depth ...er increasing from 200 to 1700 fathoms within a very few miles. At the greatest of these depths, it was supposed that the cable did not touch the ground at less distance than two miles from the ship; it may therefore be supposed that much care was required to prevent the snapping asunder, seeing that the so-called 'cable' was after all very little more than an inch in thickness. The *Sphinx* puffed and blowed to keep up with the *Great Eastern*, but the latter went steadily on her way rejoicing. Lat. at noon 52° 19′, long. 15° 10′; 180 miles distance, 192 miles paid out.

July 27.—All went on so pleasantly that, to use the words of Dr Russell, 'the conviction grew that the work was nearly

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accomplished. Some were planning out journeys through the United States; others speculated on the probability of sport in Newfoundland: the date of our arrival was already determined upon. The sound of the piano, a tribute to our own contentment, rose from the saloon; and now and then the notes of a violin became entwined in the melodious labyrinth through which the amateur professors wandered with uncertain fingers. The artists sketched vigorously. Men stretched their legs lustily along the decks, or penetrated with easy curiosity for the first time into the recesses of the leviathan that bore them.' Lat. at noon 52° 34′, long. 19° 1′; 320 miles distance, 358 miles paid out.

July 28.—So smooth and successful that there was almost a monotony in the comfort. The black hull of the *Terrible* was near at hand on the port beam; but the *Sphinx* quite distanced, and out of sight. Lat. at noon 52° 45′, long. 23° 16′; 476 miles distance, 532 miles paid out.

July 29.—Troubles enough were now at hand to prevent the monotony of success. The electricians found what they call 'dead earth'—that is, an utter stoppage of electric current through the cable. The ship was stopped, the tests were applied, and the fault was found to be not far from the ship. The old saddening routine had to be resumed—paying out stopped, ship reversed, and hauling in commenced. Slowly the cable reappeared on board, until, shortly before midnight, the faulty portion came up, to be examined at leisure. Lat. at noon 52° 38′, long. 27° 40′; 636 miles distance, 707 miles paid out; 2000 fathoms water.

July 30.—Anxiously did the electricians speculate on the misbehaving portion of cable; but they postponed examination till next day, wishing to make a new splice and speed on. They did so; electric communication with Valentia was restored, and the *Great Eastern* again steamed westward. Lat. at noon 52° 30′, long. 28° 17′; 650 miles distance, 745 miles paid out.

July 31.—A jury of inquiry was held on the offending bit of cable, which had been cut out from the rest for examination;

when lo! a bit of iron wire was found driven so forcibly through the cable as to impress every one with the opinion that it had been driven in by design, not accident. Gloomy whisperings went around, and 'cable assassin' was a designation for the first time heard. The tank-men vowed 'Lynch law' against any of their number (*if* of their number) who had done it; and the gentlemen on board formed themselves into a volunteer guard, to watch the tanks night and day. Lat. at noon 52° 9′, long. 31° 53′; 793 miles distance, 903 miles paid out. The ship was now nearer to Newfoundland than to Ireland, having passed the half-way.

August 1.—A day free from disaster. The ship went on steadily, paying out as she went. But those on board could not forget the incident of the mischievous bit of wire, nor certain hints as to predetermined mischief-makers; and these hints were all the more unpleasant because their truth could neither be proved nor disproved. Lat. at noon 51° 53′, long. 36° 4′; 948 miles distance, 1082 miles paid out.

August 2.—This day was the 'beginning of the end,' the commencement of the great final disaster. In the midst of rather gloomy and rough weather, another stoppage of the electric current was perceived; and this was followed by another series of those disheartening labours, undoing what had been already done. Another piece of wire was found sticking in the cable, and destroying insulation; and this presented such an appearance as led many observers to believe that it was part of one of the sheath wires, broken and dislodged by accident. Hence the 'cable-assassin' hypothesis now alternated with a 'cable-suicide' hypothesis; many persons believing that the mischief was due to the cable itself, and not to external villainy. But worse than this was at hand. While the *Great Eastern* was hauling in the cable mile by mile, a snap was heard, the cable had parted through excess of strain, and the end flew over the ship's side, sinking to the bottom in 2000 fathoms water! 'It was enough to move one to tears,' says the narrator; 'and when a man came with the piece of the end lashed still to the chain,

and shewed the tortured strands, the torn wires, the lacerated core, it is no exaggeration to say, that a feeling of pity, as if it were some sentient creature which had been thus mutilated and dragged asunder by brutal force, moved the spectators.' What a task was that which the engineers now undertook! They had to grope for the end of a cable down two miles and more in the depths of the ocean, and fish it up how they could. A grapnel or five-armed anchor was fastened to the end of a strong five-mile iron-wire rope, and thrown overboard. The ship then steamed slowly *across* the line in which the cable was supposed to be lying on the soft sea-bottom, in the hope that the arms of the grapnel would catch hold of the loose end. These arms were, in fact, 'hooks with which the giant Despair was going to fish from the *Great Eastern* for a take worth, with all its belongings, more than a million sterling.' No less than 2500 fathoms of wire rope were needed to take the grapnel to the bottom. And so this weary day ended. Lat. at noon 51° 25′, long. 39°; 1064 miles distance, and 1186 miles paid out.

August 3.—Still groping and groping when the day dawned. At 6 in the morning a sudden drag or pull led the engineers to believe that the grapnel had caught hold of something; and in the hope that this 'something' might be the cable itself, they began to haul up the grapnel again. If the wire rope had been in one piece, this might perhaps have been done; but it was in pieces of 100 fathoms each, fastened end to end by iron shackles and swivels. One of these swivels broke, after several hours' labour; and grapnel as well as cable went to the profound deep, carrying 1400 fathoms of the wire rope with them. It was a bitter and gloomy moment, and a fog did not lighten their difficulties; but all hope was not yet gone. Another grapnel was fastened to another length of rope ready for using, and then another groping by a passage of the great ship to and fro over the spot where the cable was supposed to lie.

August 4.—Fog and despondency were poor companions with which to begin the day. At noon the ship was believed to be 46 miles eastward of the end of the cable, and in 2300 fathoms

water. A large buoy, painted red, surmounted by a black ball, and this by a red flag, was fixed to a strong timber raft, and attached by a sufficient length of cable to a mushroom anchor; it was thrown overboard in lat. 51° 28′, long. 38° 43′, as near as could be guessed to the spot where the grapnel rope had parted. This buoy 'No. 1' was to serve as a guide.

August 5.—More fog, and great difficulty in getting the ship in the desired direction. No astronomical observations could be made; and as latitude and longitude were uncertain, no one knew whether the ship was really passing over the unfortunate cable or not. It was as much as the *Great Eastern* and the *Terrible* could do to get a glimpse of the little red flag of the buoy once now and then.

August 6.—Sunday, and a very gloomy one—fog, mist, rain, drizzle; and the mighty ship trying to get into and keep in a proper position for the search. But as buoy and sun were alike invisible, no one could tell when the proper moment would arrive for throwing the second grapnel overboard. It was a sore trial to the temper and firmness of all.

August 7.—The buoy coming again within sight, the second grapnel was heaved overboard about noon, and then the *Great Eastern* began her strange operations of groping. At six in the evening, the grapnel seemed to grasp hold of something; and again the hauling up was resumed, to be continued for hours.

August 8.—Another raising of hopes to be followed by another disappointment. About a mile of wire rope was hauled up, when a swivel gave way, as in the former case; and there went to the bottom a mile and a half of wire rope, the second grapnel, and (as was reasonably supposed) the precious cable itself, the object of so much cost and anxious care. Buoy No. 2 was at once lowered, with 2500 fathoms of wire rope, to denote the spot; and then the engineer prepared for one more attempt to grope for the hapless cable at the bottom of the deep ocean.

August 9.—Carpenters and smiths preparing a third grapnel, seamen managing the *Great Eastern* in a sea that was becoming

very rough and stormy, and officers trying to determine their exact locality under adverse circumstances—so passed the day.

August 10.—The buoy having been found, and a position taken up, the third grapnel was cast overboard, and the *Great Eastern* steamed or rather drifted along slowly, to enable the grapnel to catch hold of the missing cable.

August 11.—The final struggle—the last act of this unprecedented drama. The grapnel having shewn signs of weakness, was raised and readjusted, and again lowered with all the remaining wire rope which the ship contained. Again the grapnel grasped the cable, again the grapnel rope was raised, again it snapped before the cable itself came to the surface. All was over; there was no more rope left for experimental trials; the cable was left to rest with its predecessor, at the bottom of the Atlantic; and the *Great Eastern* returned with her mournful message to Ireland, which she reached August 17.

The history of engineering enterprise scarcely presents a parallel to this alternation of hopes and fears—this fishing for something that lay two miles deep in the ocean—this thrice grappling, thrice partial raising, and thrice losing of the mysterious cable. The heroic men on board the *Great Eastern* scarcely knew what sleep was. They watched and worked night and day, trying to avoid accidents, seeking to discover them as soon as made, endeavouring to ascertain how they had arisen, devising modes of cure, and applying the cure as rapidly as possible. It was mental discipline of a high order, but it imposed a severe tax on the senses and the bodily powers.

§ XIII. THE CABLE TRIUMPH OF 1866.

In the autumn of 1865, the directors of the Atlantic Telegraph Company had the self-same question to answer which had confronted them in the autumn of 1858—Should they succumb to their troubles, or adopt the course recommended in the school-

song, 'Try again?' They were not long in deciding. They knew that 4000 miles of cable were now lying silent and useless at the bottom of the Atlantic; they knew that unless something were done, the cable must there remain, as valueless as so much sea-weed. But they knew also the latitude and longitude of the spots where the two cables had been abandoned; and their scientific advisers, trusty men all, declared that the difficulties were surmountable—by greater care in the construction of the cable, by improved pick-up machinery, and by placing this machinery in better relation with the paying-out apparatus.

In October 1865, the directors of the company announced an intention to raise new capital, and renew the operations in 1866; but at the same time it was rendered abundantly clear that an enormous preference dividend of no less than 12 per cent. would be needed to induce capitalists to supply the money. Even this temptation was not strong enough; and it was not until March 1866 that the financial arrangements were effectually made. The plan was a remarkable one. A new company was formed, the *Anglo-American Telegraph Company;* this was to bear such a relation to the old *Atlantic Telegraph Company,* that if the cable-laying should be successful in 1866, a large preference dividend should be paid to the former before any dividend to the latter. The new company raised £600,000 to make a new cable, and to try to recover and utilise the old one. The *Telegraph Construction and Maintenance Company* undertook the work—to receive £500,000 for the new cable, whether it succeeded or failed, or £600,000 if it succeeded, or £737,140 if both cables, old and new, came into successful working-order. A fourth company, the *Great Eastern Ship Company,* agreed to lend and work their ship for a certain period for the sole duty of cable-laying, at a stipulated price. Thus four distinct joint-stock companies were required to work in harmony. As to the profits *if* the cable should at last succeed, the projectors were never tired of forming magnificent estimates; in March 1866, they spoke of a net profit of £540,000 a year from one cable only!

A new cable was put in hand, slightly differing from the former one, but similar in general construction. Of all the kinds tried by various companies, and in various seas and oceans—outside wires varying from nine to eighteen in number; light wires and heavy wires; vulcanised india-rubber to protect each outer wire; fine steel wires inside the gutta percha; saturated hemp covered with a scale of copper or brass armour; a plait of wire and hempen cords; outside wires laid parallel to the core, and bound by a plaiting of hemp; rattan canes instead of iron wires; india-rubber combined with gutta percha for the insulator; &c.—the scientific advisers saw no reason to adopt any that would depart greatly from the plan of 1865. The paying-out and hauling-in apparatus were ordered to be remodelled and perfected; and everything that skill could suggest and money purchase was directed to be provided, in order that another attempt might be made in the summer of 1866. All through the winter were they busily engaged—twisting the copper wires to form the central conductor; covering this with several alternating layers of gutta percha and Chatterton's compound to form a core; wrapping this core round with a jacket of jute or hemp; covering iron wires with strands of hemp; and coiling ten of these covered wires round the jacket or padding to form an external protector. As compared with the cable of the preceding year, this new one of 1866 had the iron wires galvanised instead of being left plain; Manilla hemp, left white instead of being tarred, covered these wires; and the fibrous jacket between the core and the outer shield or protector was made of hemp instead of jute. These changes, slight as they were, improved the cable; it weighed nearly 500 lbs. per mile less, chiefly through the absence of tar; while its strength or breaking strain was increased more than 10 per cent. It was a great effort of manufacturing, assuredly: seeing that, to make a new cable, to supply the deficiencies of the old one, and to have a surplus for slack and all contingencies, there would be required 2730 miles—nautical miles, too, which exceed English statute miles nearly as 7 to 6.

Everybody worked on with good heart. The grand ship—which has never succeeded in anything except of a grand nature, and is fitted to achieve results which would be impossible with any other vessel—was thoroughly cleaned and scoured inside and out, the tanks made worthy to receive the cable, the stern-end machinery fitted to pay it out, the bow-end machinery fitted to haul it in in case of mishaps, and the engines brought into the most perfect obedience to the commands—'Go on ahead!' 'Ease her!' 'Put her astern!' 'Stop her!' and all those other orders which 'she,' the ship, the lady of the sailor-mind, is expected to receive so submissively. And with regard to the trappings and apparatus to aid in submerging the cable, everything was brought to the most surprising degree of completeness. The smoothly working wheels and grooves to conduct the cable over the stern of the vessel; the so-called 'crinoline' which the *Great Eastern* wore (another feminine attribute of the ship) in the shape of a wire-work cage, to prevent the friction of the cable; the buoys which were to serve as floating signals when wanted; the stout ropes and grapnels likely to be wanted for raising the cable of 1865—all were as complete as money and ingenuity could make them. The electrical improvements were even greater than the mechanical, in making the sensitiveness of the copper conductor far greater than had ever before been known. A writer in the *Times*, describing the state of matters shortly before the start of the expedition, said: 'Out of the failure of 1865 has come some good; for in the interim the science of making, testing, and laying cables has so much improved, that an undetected fault in an insulated wire has now become literally impossible; while so much are the instruments for signalling improved, that not only can a slight fault be disregarded if necessary, but it is even easy to work through a submarine wire with a foot of its copper conductor stripped and bare to the water. This latter result, astonishing as it may appear, has actually been achieved for some days past with the whole Atlantic cable on board the *Great Eastern*. Out of a length of more than 1700 miles a coil has been taken

from its centre, the copper conductor stripped clean of its insulation for a foot in length, and in this condition lowered over the vessel's side till it rested on the ground. Yet, through this the clearest signals have been sent—so clear, indeed, as at one time to raise the question whether it would not be worth while to grapple for the first old Atlantic cable (1858), and, with these new instruments working gently through it for a year or so at least, make it pay its cost.'

The conductivity of the wires had by this time been so exactly calculated, that electricians announced: 'The resistance of a conductor is directly proportional to its length, and inversely to its thickness;' that 'the number of signals practicably perceptible in a second, varies inversely as the square of the length of the cable;' that 'the useful limit will be somewhere between one signal and twenty-five signals per second, according to the perfection of the apparatus and the length of the cable;' that, owing to improvements in the means employed, 'thrice as many words can be signalled in a given time in 1866 as were practicable in 1858;' that 'there are sixteen signals on an average to a word;' that 'six or seven such words can be sent in a minute;' and that, owing to the wonderfully insulating quality of the substance with which the copper wire is coated, 'it is a hundred and fifty times more difficult for the electric current to escape sideways through the gutta percha into the water, than to go all the way and back again through the wire.' And this marvellous sensitiveness had been further shewn by the instruments employed at Valentia. The cable of 1865, immersed as it was (all except a bit at one end) in the ocean, was nevertheless subjected to constant tests during the winter of 1865—6, to see whether the electric conditions remained intact; it was found that magnetic storms and electric disturbances out in the wide Atlantic sent notice of their existence in a surprising way through the cable.

All being ready, the *Great Eastern* started with her costly scientific treasure, a treasure which had had so much wear and tear of body and mind bestowed upon it. She was to have

companions out on the broad Atlantic, but from England she started alone; leaving the Nore on the 1st of July, and arriving on the 5th at Berehaven, a beautiful harbour some short distance southward of Valentia. Here she remained quiet while preparations were making for the cable. She conveyed representatives of all the companies interested in the adventure; together with numerous scientific and practical men to whom the nautical, mechanical, and electrical arrangements were subjected: such as Captain Anderson, Commander Moriarty, Mr Halpen, Mr Canning, Mr Clifford, Professor Thomson, Mr Willoughby Smith, Mr Varley, Mr Latimer Clark, &c. The great ship was also well provided with stores of every kind. On the voyage from the Nore to Ireland, a comic drama was got up and enacted, to while away an evening or two; and, in accordance with a habit very much indulged in at the present day, this drama took the form of a burlesque—the cable itself, and those concerned in it, being made subjects for puns and other light artillery.

Four other steamers, the *Terrible* (21-gun war steamer), *William Corry* (1200 tons), *Albany* (1500 tons), and *Medway* (1800 tons), were to take part in the operations. To the second of these was intrusted the duty of laying the massive shore-cable (nearly seven inches in circumference), intended to bear unharmed the friction of the beach and shallow ocean-bed for a few miles out. There were thirty miles of this cable, weighing more than eight tons to a mile, or two hundred and fifty tons altogether; and the *William Corry*, assisted by numerous boats and men, succeeded in laying the cable from the dry beach to a distance of nearly thirty miles out at sea; the land-end was then drawn up the cliff, and brought into the wooden telegraph-house at Foilhummerum. All else had their allotted duties. The *Terrible*, lent by the Admiralty for this service, was a sort of majestic guardian of the expedition, a representative of the British sovereign; she also took soundings. The *Medway* took out three or four hundred miles of the (unused) cable of 1865, and also nearly a hundred miles of massive cable to be

sunk between the island of Newfoundland and the mainland. All the ships were well provided with grapnels, mooring anchors, and buoys—the first to catch (perhaps) at the poor cable of 1865; and the mooring anchors and buoys to identify localities in the wide-spreading ocean. The grapnels were of three kinds—the ordinary five-pronged, to hook hold of the cable on the sea-bottom; the holding grapnel, to lock the cable in one of the prongs so firmly that it cannot escape; and the cutting grapnel, having a sharp edge to each prong, so placed as to sever the cable if necessary. Many miles of rope, formed of galvanised iron-wire strands bound round thickly with Manilla hemp, were provided, to lower these several kinds of grapnel to the bottom of the sea when occasion required. The grappling apparatus was distributed among all the ships, in order that simultaneous attempts might be made at different points to raise the cable of 1865, or the cable of 1866 in the event of any mishap occurring to it.

And so, on the 13th of July, off they set. The *Great Eastern* came round from Berehaven, not to Valentia, but to a position nearly thirty miles out; there she took up the seaward end of the massive shore-cable, and spliced it to the end of the main cable itself. Then with cheers of 'God-speed!' from those on board the *William Corry* (the duties of this ship having ended), the mighty *Great Eastern* steamed forth, with her companions the *Terrible*, *Medway*, and *Albany*. The electricians were the most confident of all the scientific men engaged in the work; for, in the telegraph-house at Foilhummerum, they could actually tell when the *William Corry* was rolling, when pitching, and when on a level keel, during her voyage out with the thick shore-cable to the thirty-mile distance; the cable itself, by minute changes in the galvanometer, told the tale.

On the afternoon and evening of the 13th, and during the succeeding night and morning, the *Great Eastern* went on steadily, paying out the cable over the stern, free from all entanglement or difficulty: insomuch that, by noon on the 14th, she had submerged 116 knots or nautical miles in a straight-line

distance of 108 miles. In 1865, in order to keep clear of mischief, the cable had been laid (so far as it was laid at all) at a few miles distance from that of 1858 (still lying sleepy at the sea-bottom); and now it was arranged that the cable of 1866 should keep clear of both; in fact it was about midway between them—the three cables being nearly parallel. On the evening of this day, the 14th, the cable brought a message from Valentia, which had received it from London, which had received it from the Continent, announcing war news from Germany and Italy. The operation illustrated one of the many marvels of electricity; for the *Great Eastern* was moving onwards at the time; the telegram travelled after it through the ocean, climbed up through the cable into the ship, and told its story to the galvanometer. Electricity outran steam—and laughed. During the next twenty-four hours, from noon on the 14th to noon on the 15th, the ship paid out 139 knots in 128 miles distance; and in the next period of equal duration, these quantities were 137 and 115 miles respectively. Although the depth was now gradually reaching two thousand fathoms, messages were sent to and from Valentia all day long: in fact the telegrams were all the more clear the deeper they went. The cable hitherto paid out had been the surplus portion remaining from the expedition of 1865; but this being now exhausted, a splice was made with the new cable, and operations went on as before. The sea was so good-naturedly smooth on this day (the 17th) that the splicing was done as effectively as if on shore. The noon calculation told of 138 knots paid out in 118 miles straight distance, in the twenty-four hours (ship days are reckoned from noon to noon, rather than from midnight to midnight). The 18th was a day that set active fingers and wits to work; for the cable in the tank, through some mishap or other, got several hundred feet of its length into what children would call a 'tangle,' knotting and coiling up in a very inconvenient and perilous way. If this tangle had reached the paying-out apparatus, a breakage would have been inevitable; the ship was therefore stopped, and the paying-out machinery also; the tangle was dexterously disentangled, and all went well

again. It was one of the incidents which tended to shew that, however smoothly the enterprise was progressing, constant watchfulness would be needed. Captain Anderson and Commander Moriarty, meanwhile, took care that nothing should be wanting in the way of good observations and reckoning; their noon report told of 125 knots paid out in 105 miles distance, as the day's work.

On they went, the four ships, day after day: the *Terrible*, *Medway*, and *Albany* having little other to do than congratulate the *Great Eastern*, through their flag-signals. On the 19th (129 knots submerged in 122 miles), the *Great Eastern* maintained her usual speed of something under five knots an hour—a speed considered to be more safe and judicious than the higher rate adopted in 1865. The 20th brought them a little rough weather, but not sufficient to prevent them from getting rid of 127 knots of cable in 117 miles distance. On the 21st they did 136 (in 122 miles); and on the 22d, when she passed over the deepest part of the Atlantic between Ireland and Newfoundland, the *Great Eastern* submerged 133 knots in a straight-line distance of 121. Then, again—with 138–121 knots on the 23d, and 135–121 on the 24th—the ship afforded evidence of the steadiness of her progress: especially observable in the near approach to equality in the actual distance run on successive days. Sometimes clear starlight, sometimes murky weather; but it made very little difference to the progress of the ship. On the 25th, the portion of cable contained in the fore-tank was exhausted; the sea had swallowed it all; and now a splice was made with the end of the cable in the after-tank. When the splice was made, messages could be sent to and from Valentia just as clearly as if it were whole unjointed cable. This day told of 130 knots in 112 miles distance. Thoughts were now very busy in reference to Heart's Content in Newfoundland. The ship was less than three hundred miles from that harbour; all apprehension of disaster had been dismissed; and the means were now wanted for guiding the mighty ship into her haven of safety. The three other ships were told to go ahead, and tell Heart's

Content that 'all was well.' On the 26th, in so little as a hundred and thirty fathoms water, the day's work (noon to noon) was 134 knots in 128 miles; and on the afternoon and evening of that day the soundings shallowed so rapidly as to tell all on board that they had virtually crossed the Atlantic, bringing over the new cable without a single necessity for using the buoys, grapnels, mooring chains, or hauling-in apparatus. Moreover, the quantity of 'slack' or waste of cable, due to deviations in the straightness of the route, had been much less than in any of the former expeditions: to that extent insuring both economy and efficiency.

The ringing of bells, the firing of cannon, the waving of flags, and other demonstrations of joy, shewed what the small community at Heart's Content felt when, on the 27th of July, they saw the great ship enter the harbour. The news of her near approach had before been made known, and the smoke from her funnels was looked for as soon as dawn broke on this auspicious day. The *Terrible*, the *Albany*, the *Medway*, together with H.M.S. *Niger*, and several trading ships, were ready to receive the *Great Eastern*, and to guide her in safety by a line of buoys. As it was not necessary to bring the end of the cable to land, it was cut on board ship, and spliced to one end of the thick shore-cable (similar in character to the one used at Valentia). She had done her work nobly; and the *Great Eastern* now had a few days' respite, preparatory to another part of the enterprise to be described presently. Her officers could have a little rest, and a little enjoyment of the holiday scenes on shore.

On the 28th, the landing of the shore-cable commenced. The splice was submerged, and the shore-cable was borne on westward by the *Medway*, paying out as she went. When shallow water was reached, the pinnaces, cutters, gigs, and paddle-box boats of the *Terrible* and other vessels were brought into requisition, to finish the work. And last of all, in the words of one of the narrators: 'This part of the shore is fringed with huge boulders of rock, so that the boats could not get within twenty yards of the beach; but the *Terrible's* crew,

accompanied by the leading cable men, under the orders of Mr Temple, jumped into the water, and there was a hearty and animated struggle between them to see who should first bring the cable on shore.' The population of Heart's Content is but small; but almost every one was on the beach, besides three directors of the Company, who had come from London. The end of the cable was carried carefully to a telegraph-house erected near the beach, where the requisite instruments for testing and signalling had been provided. Great was the joy of all when the cable spoke; signals were sent to and from Ireland with ease and precision. Mr Gooch, among others, was at Heart's Content; Mr Glass, among others, was at Valentia; and the following telegram was speedily sent by Mr Gooch, to be forwarded to the Secretary of State for the Foreign Department: 'Mr Gooch has the pleasure to inform Lord Stanley that the Newfoundland shore-end of the Atlantic cable was laid to-day, and the most perfect communication established between England and America. God grant it may be a lasting source of great benefit to our country.' Speedily was sent off a much longer telegram to Mr Glass, who, as managing director of the company by whom the cable was made, had ample reason to desire the success of the great undertaking: 'Our shore-end has just been laid, and a most perfect cable, under God's blessing, has completed telegraphic communication between England and the continent of America. I cannot find words fully to express my deep sense of the untiring zeal and the earnest and cheerful manner in which every one on board, from the highest to the lowest, have performed the anxious and arduous duties they in their several departments have had to perform. Their united energy and able and watchful care, night after night for the period of two weeks required to complete this work, can only be fully understood and appreciated by one who, like myself, has seen it. All have faithfully done their duty, and glory in their success, and join with me in hearty congratulations to our friends in England who have in various ways laboured in carrying out this great work.'

In this year, as in 1858, royalty shewed its appreciation of the grandeur of the fact achieved. Nearly the first message transmitted outward, from the Old World to the New, was from Queen Victoria to President Johnson:

'*The Queen, Osborne, to the President of the United States.*

'The Queen congratulates the President on the successful completion of an undertaking which, she hopes, may serve as an additional bond of union between the United States and England.'

Some little management was required in forwarding this telegram, owing to the imperfect state of the cable submerged from Newfoundland to the mainland of America. Captain Bruce, in H.M.S. *Niger*, took charge of the message, and conveyed it to a point where the land-wires flashed it onwards to Washington. It was anything but lightning speed from Heart's Content to the mainland. On the 30th, the President sent off his reply, which reached Heart's Content at 3.42 P.M. on the 31st.

'*The Executive Mansion, Washington*, 11.30 A.M., *July* 30.

'To Her Majesty the Queen of the United Kingdom of Great Britain and Ireland.—The President of the United States acknowledges with profound gratitude the receipt of Her Majesty's dispatch, and cordially reciprocates the hope that the cable that now unites the eastern and western hemispheres may serve to strengthen and perpetuate peace and amity between the government of England and the republic of the United States.

ANDREW JOHNSON.'

The forwarding of this telegram to its destination was a remarkable achievement; the message, as we have said, was received at Heart's Content at 3.42 P.M.; and at 5.0 P.M., or in about an hour and a quarter, Mr Gooch received intimation that it had reached the Queen at Osborne. About an

hour and a quarter had sufficed to spell out the message letter by letter, send it through the cable to Valentia, across Ireland to Dublin, across the Irish Sea to Holyhead, across Wales and England to Hampshire, across the Solent to the Isle of Wight, and along a portion of the island to Osborne; and then to send an acknowledgment back through the same intricate route. It was justly a marvel to the world, although electro-telegraphers are too much accustomed to marvels to think much of it. The President and Mr Seward sent congratulatory telegrams to Mr Cyrus Field, as the representative of the Republic in the enterprise; the Lord Mayor of London exchanged greetings with the Mayor of New York; and a very characteristic transmission of congratulations took place between two civic dignitaries who had not only an ocean but a continent between them:

'*Franklyn, Mayor, Vancouver, July* 31; *to the Lord Mayor of London.*

'The infant colony, Vancouver, eight thousand miles distant, sends telegraphic cordial greetings to Mother England.'

The Lord Mayor took upon himself to answer for Britannia in the following terms:

'Mother England acknowledges the cordial greetings of her son Vancouver. May peace, good-will, and unanimity unite and prosper our happy family.'

It was now possible to send a telegram from San Francisco to Ceylon, across the three continents of America, Europe, and Asia, and across the Atlantic and Indian Oceans; indeed, this was actually done from San Francisco as far as Bombay, very soon after the cable was laid. Commercial telegrams—by which the vast cost of the whole work is eventually to be defrayed—were speedily commenced; and English merchants knew the prices of Chicago flour, 'bowed Georgia,' and

on the 12th. The naval officers and the engineers, after a brief conference, settled their plan of operations; partly to make combined dredgings with the grapnels, and partly to keep watch over the signal buoys, any drifting of which would have seriously disturbed the cable-fishers. There then ensued a series of operations very tiresome to those who had to conduct them. Sometimes the weather was so foggy that the seamen could scarcely see a yard ahead; sometimes, even when the fog cleared away, the dancing floating buoys could not be caught sight of; sometimes the wind was too faint to carry the ship drifting over the cable; and sometimes, again, an increased strain on the grapnel rope led to a fallacious hope that the prongs had grasped the much-wished-for cable. These trials of patience occurred on the 13th and 14th, and again on the 15th and 16th. There was really cause for believing that, on the last-named day, the cable was caught, and attempts were made to buoy it; but unfortunately the splice between the grapnel-rope and the buoy-rope parted, and down went the former—carrying grapnel and probably cable with it to the bottom. To try again was the maxim and motto of all on board; the idea of defeat was scouted. Again was a grapnel lowered on the 17th. The position was evidently a good one; the grapnel caught the cable; the hauling-in apparatus was set to work, and—to the intense joy of all—the cherished cable came up into sight, the veritable cable which no human eye had seen for twelve months. But, alas! while the eager officers and crew were looking over the bows of the ship at the recovered treasure, the rough weather caused the cable to disengage itself from the prongs of the grapnel, and down it went, dashing once again the hopes of Mr Canning and his companions. Even this brief glimpse, however, gave satisfaction to the electricians; for they observed that nearly half the circumference of the cable was untouched by the muddy ooze which had stained the other half: shewing that it had lain quietly on a smooth bed, neither sinking so deeply into it as to be beyond the reach of grapnels, nor, on the other hand, exposed to any sharp edges or rough stones. There was a depth

of at least two miles of water under the ship, at the time when this mishap occurred.

Four ships steaming about, sometimes looking after buoys—which had a tendency to break loose from their moorings in rough weather—sometimes dredging with the grapnels, and anon asking each other by signals whether they had caught anything. It was a singular scene, unlike anything that the world had before witnessed. After the mingled success and disaster on the 17th, the ships on the 18th were keeping a watch on the buoys. On the 19th, the *Albany* and the *Great Eastern*, with grapnels down, both felt a tug as if the cable had been caught; concerning the *Albany*, there was a doubt; but all the officers in the *Great Eastern* felt pretty certain that *their* catch was a real one. The grapnel was raised some 1300 fathoms or so, and was then buoyed in that position, to await a steady sea to complete the raising—a matter of much importance, seeing that the greatest hazard of some disaster or other occurs when the grapnel and cable get near the surface. Something wrong again occurred, and the 20th and 21st were spent in another battle with the buoys and the grapnels.

On the 22d the *Terrible* wished her companions adieu, and steamed back to Heart's Content, being too short of coals to remain longer out in mid-ocean. Signalling in plenty took place between the three remaining ships on the 23d, each exchanging hopes, fears, suggestions, and information with the other two. There was constant running after the buoys; when there was a good sea for grappling, the ships were not in a right position; and by the time a right position had been attained, the sea became rough again. So it was on the 24th, and so on the 25th. Mr Canning and his colleagues became a little downcast, seeing that the recreant cable had in some way or other eluded all their efforts. The buoys were even more troublesome than the cable, for they sometimes turned bottom upwards, and at other times drifted away altogether. On the 26th, after a hard day's dredging, the *Great Eastern* found that two of the prongs of her grapnel had been bent and injured, as if by dragging at

It was right that, at a banquet given to the heroes of the Atlantic Telegraph at Liverpool in October 1866, the Prime Minister should be able to announce that the Queen had bestowed a baronetcy on Mr Gooch, and knighthood on Captain Anderson, Mr Canning, Professor Thomson, and Mr Glass. Such honours may not be very scientific, but they were richly deserved.

Professor (now Sir W.) Thomson, at another banquet given by the Lord Mayor on October 30, made some excellent observations on the scientific aspects of the great cable-laying achievement; pointing out that, however right it may be that science should receive adequate pecuniary reward, science should nevertheless be pursued for its own sake—certain of a favourable result to mankind some time or other. 'Unless men of science pursue their studies out of a pure love of knowledge, or from an abstract desire to become acquainted with the laws of nature, they will seldom carry on their labours with success; but, at the same time, no greater reward could crown their investigations than when, as in the case of electric telegraphy, they are the means of conferring a practical service on mankind, the value and importance of which are admitted on all hands. The history of many of the most important discoveries shews that they were the result of investigations carried on from a pure love of science, and a desire to increase our acquaintance with the mysterious powers of nature. Who could have supposed that the years which Stephen Grey spent in discovering and defining the law of electrical conductivity as a distinct property of nature, would lead to a discovery by which the most distant nations of the earth would be brought into immediate communication with each other, and which would be celebrated in the middle of the nineteenth century by the representatives of the wealth and commerce of the English metropolis? Or who would have supposed that the discovery of the relation between the laws of electricity and magnetism—or that Faraday's investigations into the properties of matter in reference to electricity, and his announcement that

gutta percha was the best insulator—would have borne rapid fruit in the thousands of miles of electric cable which are now the means of conveying intelligence to and from every portion of the globe? My only object in these remarks is to point out that science, to be true to itself, must be followed for its own sake, and that all the most important services it has rendered to mankind have been the result of arduous investigations, carried on by men animated with the hope of no other reward than that which awaits every sincere and industrious student of nature.'

§ XV. OTHER ATLANTIC CABLE PROJECTS.

THE future of electro-telegraphy is now pretty well defined in its general character, if not in its topographical details. Every country, unless very low down in civilisation, is gradually spreading a net-work of wires over the land; every ocean and sea, unless far removed from the routes of daily commerce, is gradually receiving telegraphic cables in its waters. Those nations which have done much, will still do more; those which have hitherto achieved nothing will, one by one, enter the list of competitors for the advantages of rapid communication; while improvements in cable-making and submersion, and in the construction and management of electro-magnetic apparatus, may very fairly be looked forward to.

One large class of undertakings to which a good deal of attention has been paid, has for its object to obtain a new route from Europe to America by a series of comparatively short cables, instead of one cable of greater length. When the success of the great works (just described) in 1866 could not have been safely predicted, many projectors came forward with schemes for spanning the Atlantic by other routes. Maps and charts were studied, to see what points of land might possibly be utilised as

Lighter, smaller, cheaper, handier, swifter in transmission—Mr Allan's cable has indeed much to do to justify these encomiums, against the counter-opinions of the older Atlantic electricians.

Another scheme is of French origin—to start from Cape St Vincent in Portugal, and submerge successive portions of cable to the Canary Islands, Cape de Verd Islands, Senegal, Brazil, West India Islands, and United States. Land-telegraphs at the several islands and coasts would enable the submarine portions to be made shorter, and would, at the same time, develop new sources of trade.

The past history of electro-telegraphy has been too grand, too wonderful, to warrant any prediction of failure or impossibility in such schemes as the above. Practical science has so often put to shame the foretellings of those who dwell too implicitly on deductions from theoretical formulæ, that we must leave the future to tell its own tale as to the reliability of cable-projects. A striking proof of the vast powers of the whole system was afforded by one of the cheap London newspapers at the end of October 1866. A speech made by Mr Bright at Dublin was not ended until eleven o'clock on the evening of the 30th; it was transmitted word by word, or indeed letter by letter, through the Anglo-Irish cable, from Dublin to Holyhead, and thence by land-wires to London; the transmission ended at three o'clock in the morning of the 31st; and the report filled four columns of that day's issue of the *Daily Telegraph*. This was said to be the longest telegram ever sent through a submarine cable.

Annals of Telegraphy from 1815 to 1866.

As the practical adoption of electric and magnetic agency in telegraphy was not reduced to a system until about thirty years back, it may be useful to give the dates of some of the scientific discoveries and inventions which rendered such a system possible. A few of the more prominent matters only need be mentioned here.

1815. Sir Home Popham's semaphore adopted by the Admiralty.
1816. Ronalds worked eight miles of telegraphic wire by electricity.
1817. Hansteen published his researches on the magnetism of the earth.
1818. Night semaphores, for land and sea, introduced.
1819. Oersted discovered the action of electric currents on magnetic needle.
1820. Ampère suggested the possible application of Oersted's discovery to telegraphy.—Schweigger's galvanometer invented.
1821. Ampère established the laws of electro-magnetic action.
1822. Seebeck discovered thermo-electricity.
1823. Ronalds proposed to the Admiralty the adoption of an electric telegraph, for government purposes.
1825. Becquerel ascertained the electric conductivity of various metals.
1827. Sir Snow Harris discovered inductive action of magnets on soft iron.
1828. Siberian magnetic pole discovered by Hansteen.
1830. Faraday commenced researches on current induction.
1831. North American magnetic pole ascertained by Sir J. C. Ross.
1832. Barlow's researches on the electric origin of the earth's magnetism.
1833. Faraday's law of electro-chemical action announced.—Gauss and Weber worked a short electric wire at Göttingen.
1834. Wheatstone ascertained velocity of electric current.
1835. Jacobi's magneto-electric machine invented.
1836. Daniell's constant galvanic battery introduced.
1837. Cooke and Wheatstone, Steinheil, and Morse brought forward their first electric telegraphs.
1838. Successive improvements made and adopted by the above-named inventors.
1839. Morse proposed the determination of longitudes by the electric telegraph.